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The Scientific Glassblower

Advances in science and technology are being made at breakneck speed. Many of these achievements, already obsolete by the time they are perfected, immediately give way to still newer concepts in a never-ending procession. World-wide publicity of satellite launchings, advances in medicine, chemistry, optics, communications, and many other fields has provided all science with a new aura of respect and prestige.

It is the scientific glassblower who must translate many theories of the scientist into practical, working techniques; indeed, he has become an indispensable part of the scientific community. Consider, for example, Fahrenheit, an early glassblower who made the thermometer possible. Consider also the vacuum tube, a major component in the vast field of electronics.

That this is so was quite evident during the Sixth Symposium of the American Scientific Glassblowers Society held in May in New York City. Here papers were presented on various studies of glass, annealing, radioactivity, vacuum envelopes, and the importance of the glassblower to the scientist. Workshop sessions offered a lively exchange of technical information among glassblowers.

The Society has contributed greatly to the development of the modern scientific glassblower and is now making plans for its tenth anniversary next year. The future is assured, judging from the fact that almost every scientific and industrial organization in the United States has on its staff at least one skilled glassblower. With research increasing at the rate of 8 per cent a year, industry now has need for about five times as many scientific glassblowers as there are trained men available.

Recent Techniques for the Chemical Analysis of Glass

by J. P. Williams Research and Development Division, Corning Glass Works

IN THE PAST TEN YEARS, great strides have been made in the scope and speed of chemical analysis. Knowledge of chemical composition is important in the manufacture of glass because this information is essential to uniformity and control of the product. This report will review a number of current methods in use for the chemical analysis of glass and silicate materials.

The methods described are, for the most part, instrumental in nature and represent a wide scope of instrumentation. The sample preparations necessary range from simple flat pieces of glass, or powdered glass, to complete wet chemical solution of the sample. Under ideal conditions all of these methods are capable of an accuracy of 1 to 2 per cent of the amount of the element determined.

When rapid analyses are required, and when glass compositions are reasonably uniform, such instrumental techniques as direct-reading emission spectroscopy and X-ray spectroscopy are used to an advantage. Where glass compositions vary to some extent, instrumental methods less sensitive to sample matrix are employed. Flame photometry and polarography are typical examples. Finally, for umpire analyses, for analysis of standards used in the above-mentioned techniques, and for analysis of complex materials, classical wet methods must be brought to bear. While often tedious and time-consuming, they are the necessary back bone of analytical chemistry.

Analytical Techniques

Table I summarizes (*1*) a number of techniques for the quantitative chemical analysis of glass, (*2*) the type of problem for which each is used, and (*3*) the elements determined by each method. Since this report is concerned with more recent developments in the field of glass analysis, no attempt has been made to include in this table the so-called classical methods of analysis, important as they maybe. Reviews of these classical methods of silicate analysis[1, 2] are available, however.

Direct Reading Emission Spectroscopy

Probably one of the most significant recent advances in the rapid analysis of silicate materials has been the application of the direct reading, or recording emission spectrometer, to non-metallic materials. While it has been used for years in the metals industry it has only recently been successfully applied to accurate silicate analysis[3, 4]. Instrument conditions and sample preparations vary and are undergoing modification. One pro-

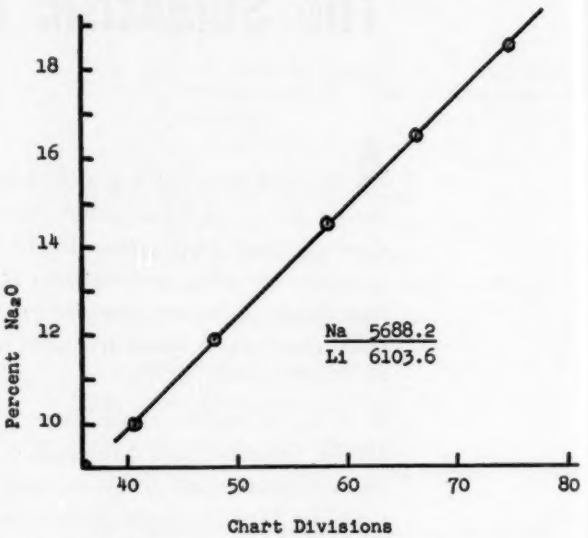

Fig. 1. Analytical curve for Na_2O in lime glass direct-reading emission spectrometer.

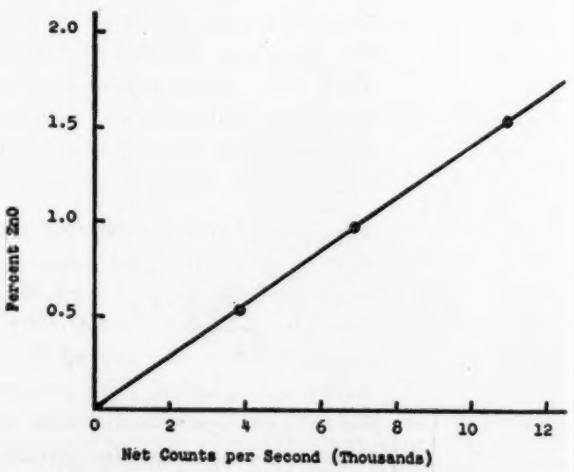

Fig. 2. Analytic curve for ZnO in glass X-ray emission spectrometer.

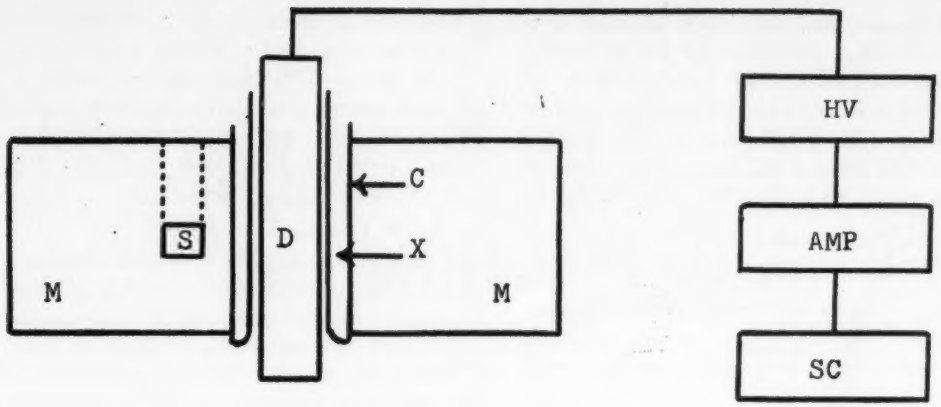

Fig. 3. Apparatus for neutron absorptiometry.

Table I

QUANTITATIVE ANALYTICAL TECHNIQUES

Technique	Use	Elements Determined
Direct-reading emission spectroscopy.	Production glasses where matrix is constant.	Al, Na, Ca, Mg, and many others.
X-ray spectroscopy.	Production glasses where matrix is constant.	Cd, Zn, Pb, As, Sb, Sn, Ti, Zr, S, Se, Cu, Ag, Au, and others.
Polarography.	Production glasses and most other nonroutine silicates.	Pb, Cd, Zn, Sb, and other reducible elements.
Flame photometry.	Production glasses and most other nonroutine silicates.	Li, Na, K, Rb, Cs, Ca, Mg, Ba, and others.
Spectrophotometry.	Production glasses and most other nonroutine silicates.	Si, Al, P, Mn, Ti, Fe, and others.
Neutron absorption.	Production glasses where matrix is constant.	B
Pyrohydrolysis separation.	Production glasses and most other nonroutine silicates.	F, Cl, B

cedure for using this device is shown in Table II, and a resulting analytical curve is pictured in Fig. 1.

X-Ray Spectroscopy [5, 5a]

X-Ray fluorescence has proved to be an excellent means for the analysis of many elements in glass where the glass matrix remains reasonably constant. It has been used to good advantage in production glasses where such elements as sulfur, zinc, cadmium, selenium, zirconium, silver, gold, arsenic, antimony, tin, lead, and titanium have been determined[6, 7].

Most glasses are composed primarily of low atomic number elements which places some limitations on this analytical technique. For example, slight changes in silicate matrix by alterations in heavier element concentration may result in difficulties by shifting instrument response for the element being determined. For elements between atomic number 13 (aluminum) and atomic number 22 (titanium) the use of a vacuum or helium path for the X-ray optics as well as a gas flow counter is required; often, with these elements, instrument response and sensitivity leave something to be desired. However, the advantages of speed and nondestructive analysis make X-ray spectroscopy an important tool for the analysis of elements of atomic number greater than 21, and continuing improvements in instrumentation may soon extend the range of usefulness to lower atomic number elements.

To illustrate the application of X-ray fluorescence analysis to glass, Table III gives instrumental conditions necessary to obtain the analytical curve in Fig. 2.

Table II

DIRECT-READING EMISSION SPECTROMETER

Instrument:	Applied Research Laboratories 2 Meter Production Control Quantometer and Multisource Unit No. 4.
Sample preparation:	Modification of Alcoa method[3]. Lithium, the internal standard, is introduced by fusing the glass sample with $Li_2B_4O_7$. The fusion is ground, mixed with graphite and briquetted.
Methods:	The briquetted samples are analyzed by the Pellet-Spark technique using a high-voltage condensed spark with added inductance and a 20-second integration period. Intensity ratios are recorded automatically on the chart recorder and can readily be converted to per cent oxide.

Table III

X-RAY EMISSION SPECTROSCOPY

Instrument:	North American Philips, Type 52260.
Sample preparation:	Flat solid section ground with 400 mesh SiC.
X-Ray tube:	FA-60 tungsten.
X-Ray tube voltage:	40 kv, 25 ma.
Analyzing crystal:	LiF.
X-Ray path:	Air.
Collimator:	0.020-inch parallel plate.
Detector:	Scintillation.
Analysis line:	Zn K_α 1.43 Å.

Polarography[8]

Compared to the recording emission spectrometer and X-ray spectroscopy, polarography is a slower method of analysis since the glass sample must be dissolved before an analysis can be made. Once the sample is in solution, however, rapid estimation of many reducible elements is possible. This method is not seriously af-

fected by fluctuation in glass matrix, although certain elements may interfere with a specific determination.

The polarograph can be used for the analysis of a large number of reducible ions and has been specifically applied to the analysis of cadmium, zinc, and lead[9] and for antimony[10] in glass. Conditions for the determination of these elements are given in Table IV.

Table IV

POLAROGRAPHIC ANALYSIS

Instrument:	Leeds and Northrup electrochemograph, Type E.
Electrode:	Dropping mercury.
Sample preparation:	Sample dissolved using hydrofluoric acid.

Element	Cadmium	Zinc	Lead	Antimony
Supporting electrolyte.	1M NH_4OH plus 1M NH_4Cl plus 1M$(NH_4)_2$ $HC_6H_5O_7$		1M HNO_3	N/2 HCl plus N/2 $H_2C_4H_4O_6$
Half-wave potential (volts).	-0.8_2	-1.3_5	-0.4_5	0.2_0
Diffusion current constant.	3.5_1	3.6_2	3.6_5	3.8_1

Flame Photometry[13a]

The flame photometer is a most versatile tool for the analysis of the alkali elements in glass. After solution of the sample, the method is rapid and accurate and is subject to relatively few interferences[11]. With a suitable monochrometer and flame source, the technique can be standardized to analyze glasses and similar materials for alkalies over wide ranges of composition[12]. There are a large number of elements which are readily excited at flame temperatures[13] and flame photometry can be extended to include calcium, magnesium, and barium[14] in glass as well as other elements. Table V summarizes specific instrumental conditions for the estimation of a number of elements commonly found in glass.

Table V

FLAME SPECTROPHOTOMETRIC ANALYSIS

Instrument:	Beckman DU spectrophotometer with flame attachment No. 9200. Beckman oxygen-hydrogen burner No. 4020 and photomultiplier No. 4300.
Sample Preparations:	Sample dissolved using hydrofluoric acid. Analysis of solution without removal of hydrofluoric acid possible.

Element	Instrumental Conditions		
	Analytical Line ($m\mu$)	Slit Width (mm)	Concentration Range (ppm)
Lithium	671	0.3	0 to 20
Sodium	589	0.1	5 to 25
Sodium	589	0.2	0 to 8
Potassium	767	0.1	5 to 25
Potassium	767	0.3	0 to 15
Rubidium	795	0.3	0 to 20
Cesium	852	0.3	0 to 20
Calcium	625	0.1	0 to 60
Calcium	625	0.2	0 to 20
Magnesium	371	0.2	0 to 100
Barium	873	0.5	0 to 100

Spectrophotometry

Colorimetry has been used for many years in chemical analysis. Any discussion of recent trends in silicate analysis should, however, include the expanded application of colorimetric or spectrophotometric methods, and this trend can be best illustrated by the work of Shapiro and Brannock[15]. These authors outline a scheme of rapid silicate analysis based almost entirely on colorimetric procedures, many of which are readily adaptable to a wide variety of glasses.

Radio Chemical Analysis

Boron is unique in that it has a cross section (absorption) for thermal neutrons, which is hundreds and, in some instances, thousands of times greater than that of many elements commonly found in glass. This strong absorption serves as the basis of a rapid and selective method for estimating the boron content in borosilicate glasses[16]. While this method is not sensitive to low concentrations of boron, it does provide an excellent means of monitoring borosilicates where the boron concentration is greater than 5 to 10 per cent. A schematic drawing of an apparatus for neutron absorptiometry is shown in Fig. 3.

Pyrohydrolysis Separation

With few exceptions, the instrumental methods mentioned above are all subject to interferences of one kind or another. This illustrates the well-known fact that the analytical separation of the element being determined from interfering elements is often more difficult than the actual determination of an isolated constituent. Methods for the selective isolation of elements are of extreme importance, and pyrohydrolysis offers an excellent means for the separation of the halogens from many glasses. The application of pyrohydrolsis to the separation of fluoride has proved most successful[17], and the separation of boron has been useful in certain instances[18]. At the present time the pyrohydrolytic distillation of fluoride from glass offers an efficient means for the analysis of this element which has not yet been challenged by instrumentation.

ACKNOWLEDGMENT

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ACS Glass Division Papers

The first of two reports covering papers delivered at the Society's 63rd Annual Meeting.

The 63rd Annual Meeting of the American Ceramic Society was held in Toronto, Ontario, Canada, April 23-27, 1961, at the Royal York Hotel. Registration for the meeting totaled about 2200 men and 300 women. The many visitors from Mexico, Great Britain, Germany, Japan, and a number of other countries made this a truly international gathering.

The following is a report on the joint symposium entitled "Nucleation and Crystallization in Glasses and Melts," presented April 24 by members of the Basic Science and Glass Divisions. Co-chairmen were W. D. Hillig, General Electric Co., Schenectady, N. Y. (Basic Science Division), and G. E. Rindone, Pennsylvania State University, University Park, Pa. (Glass Division).

Session I, Properties and Structure—W. D. Hillig, General Electric Research Lab., Chairman

Sintered Ceramics, Glass-Ceramics, and Glass—Comparison of Characteristic Properties and Microstructure. By S. D. Stookey, Corning Glass Works. The structure and properties characteristic of ceramics made by nucleated crystallization of glass (glass-ceramics) were compared with the characteristics of glass itself and those of ceramics made by sintering or cementing oxide crystals, *i.e.* conventional ceramics in general. The oxide composition of glass-ceramic, weight per cent, was given as follows:

SiO_2 — 56
MgO — 15
Al_2O_3 — 20
TiO_2 — 9

Mr. Stookey pointed out that ceramic products having similar chemical compositions but different microstructures and properties may be manufactured by any of three basic processes: glass formation, conventional ceramic fabrication (sintering or cementation of powder), or the glass-ceramic process of nucleation by which Pyroceram materials are made. A comparison was made of the characteristic ways in which each of the processes influences microstructure and microcomposition.

Factors controlling the properties of materials having the same overall composition, but made by these three processes, include crystal composition, crystal size, crystal shape, crystal orientation, crystal concentration, matrix (glass) composition and concentration, porosity, and homogeneity. The properties affected by structure include strength, thermal expansion, elastic, thermal, electrical, and optical properties, and chemical durability.

The following conclusions concerning this particular glass-ceramic were drawn, and certain of them may apply to all fine-grained nonporous ceramics.

1. Modulus of rupture is definitely sensitive to the surface condition (polished or abraded), showing that surface flaws are important factors when the grain size is less than ½ micron (and perhaps with larger grains up to the point at which the grain diameters are comparable to the flaw depth). This is a warning that strength measurements of fine-grained ceramics lose their value if surface condition is not controlled and specified.
2. Modulus of rupture of the abraded fine-grained glass-ceramic is at least twice that of abraded annealed glass. This may be partly accounted for by the higher Young's Modulus.
3. Because surface flaws are among the controlling strength factors in this fine-grained ceramic, investigators still do not know the intrinsic strength of the material, or whether internal Griffith flaws exist in or between the crystals.
4. Modulus of rupture of abraded and polished fine-grained ceramic *increases* with crystal diameter up to at least 0.5 micron diameter. This trend is the opposite of that found in sintered ceramics having larger grain sizes (see Kingery's "Ceramic Fabrication Processes"), where the strength *decreases* proportionally with the square root of crystal size. This is true, for example, of beryllium oxide with crystals above 30 microns in diameter.
5. Strength of a fine-grained glass-ceramic can be relatively high even in the presence of many kinds of dissimilar crystals, perhaps because the micro-stresses between crystals are not so high as to produce microcacks.
6. The crystal growth in a well-nucleated glass-ceramic is not linear with time as in usual devitrification of glass. This difference stems from the fact that the process is primarily a recrystallization or coalescence of smaller

crystals, rather than crystallization directly from a homogeneous liquid.

One of the most important factors in the nucleation-controlled crystallization of glass is the reproducibility and uniformity of structure, maintainable in products even of large size. This makes possible mass production of products such as radomes, whose strength must be reliable and whose electrical properties must be extremely uniform and maintained within close limits.

Crystallization of a Titania-Nucleated Glass, By R. D. Maurer, Corning Glass Works. The invention of catalyzed crystallization of glass by spontaneous nucleation has stimulated many questions concerning the basic mechanisms in this process. In particular, it is interesting to answer those questions concerning the mode of nucleation.

The glass had an approximate composition by weight of 56 per cent SiO_2, 20 per cent Al_2O_3, 15 per cent MgO, 9 per cent TiO_2, and a few tenths per cent arsenic oxide. Blocks of this glass about 30 by 30 by 7 mm were treated in a furnace for various lengths of time with intervening cooling to room temperature for measurement. Light scattering data were taken followed by X-ray analysis.

Several heat treatments of the base glass devoid of titania have failed to achieve crystallization by homogeneous or internal nucleation. The addition of titania as a nucleating agent appears to have initiated crystallization by promoting formation of the isotropic regions ("emulsion") which are unstable toward crystallization. The significance of catalyzing crystallization by emulsion formation has been discussed by Stookey. The interfacial energy between two glasses is very small compared to the interfacial energy between a crystal and a glass. Since this comprises the barrier to nucleation, assuming the system tends to separate into two phases in bulk, emulsion formation nucleates very readily. One of the two liquids can be highly unstable and can readily crystallize, even if the original glass was stable. The system is thus effectively nucleated.

The scattering inhomogeneities initially present were shown to be predominantly isotropic and to become anisotropic during heat treatment. The isotropic-anisotropic transformation was correlated with nucleation and was interpreted as the crystallization of an "emulsion." Stookey's discussion of crystallization catalysis by emulsion formation was elaborated and the significance for theories of glass formation discussed.

Catalyzed Crystallization in Glass. By Werner Vogel and Klaus Gerth, Schott & Gen., Jena, Germany. During the melting process crystalline raw materials were changed into liquid glass melt. Frequently crystals appeared in the glass when cooling down such homogeneous melts and during the process of glassy congealing.

The paper emphasized that every crystallization in glass depends on both the glass composition and the respective latent state of arrangement of the glass components during the cooling process, *i.e.*, the respective glass structure. Separation areas are influenced by *(1)* changed concentration of certain glass components, *(2)* influence exerted by field-intensity of ions contained in the glass, *(3)* temperature-treatment of the glass, and *(4)* trace additions positively or negatively changing the surface tension of certain glass phases.

The theoretically and experimentally proven results led to research concerning crystallization in Pyroceram-type products and photosensitive glasses. In all instances theoretical reasoning could be proven by experimental results. Rather impressive proof of assumptions was also given by electron-microscopical investigations in model glasses (beryllium fluoride glasses), in which controlled crystallization was attained.

Anomalous Changes in Elastic Moduli and Refractive Indices of Some Borosilicate Glasses as the Result of Heat Treatment. Edgar H. Hamilton, National Bureau of Standards. Refractive indices and Young's modulus were determined on experimental borosilicate glasses following each of a variety of heat treatments. All glasses contained ZnO, B_2O_3, and SiO_2 as major constituents. Other constituents present in some of the glasses included Al_2O_3, MgO, CaO, SrO, BaO, TiO_2, and ZrO_2. Contrary to expectations, large decreases in Young's modulus which were not accompanied by comparable changes in refractive index were observed for eight glasses. Except for a concurrent color change in one glass containing TiO_2, no change in the appearance of the glasses was observed.

Additional observations on a number of specimens of glass of the same composition, each heat treated repeatedly at a different temperature and later at the temperature at which the color change was observed, indicated that the decrease in modulus was the result of a sequence of treatments: a *nucleating* or *striking* treatment and a higher temperature *reaction* treatment. When treated at temperatures above the nucleating temperature, specimens which had not received the nucleating treatment became opaque many times more rapidly than nucleated specimens. Differences in the sizes and amounts of the particles separating from the glass in the various specimens were offered as an explanation of the anomalous observations.

Effect of Heat Treatment on the Strength and Abrasion Resistance of a Glass-Ceramic Material. By M. Watanabe, R. U. Caporali, and R. E. Mould, Preston Lab. This report presented the results of some strength measurements on a glass-ceramic material which may be melted and formed as a glass and then converted to ceramic by subsequent heat treatment and crysallization. One of the most noteworthy characteristics of certain of such materials in the crystallized state is a high degree of hardness and resistance to abrasion coupled with a rather high strength.

The aim of the study was to examine the development of strength and abrasion resistance at various stages of

heat treatment as the material was converted from glass to ceramic. The first goal was to obtain information about the effect of the details of the heat treatment process on the resulting properties, *i.e.*, which stages are most critical and which less so, and what treatment is necessary to develop the optimum properties. The second goal was to attempt to find clues indicating which structural characteristics of glass-ceramics are primarily responsible for their hardness and strength. Composition of the glass used in this experiment as calculated from batch is given in weight per cent as follows:

SiO_2	— 80.7
Al_2O_3	— 4.0
Li_2O	— 12.4
K_2O	— 2.5
CeO_2	— 0.025
SnO_2	— 0.015
AgCl	— 0.18

The strength of a heterogeneously nucleated glass in the system SiO_2-Al_2O_3-Li_2O-K_2O was measured for both unabraded and grit-blasted specimens in the as-formed glassy state and after various stages of heat treatment with resulting nucleation and crystallization. It was concluded that the improved strength of the abraded glass-ceramic in the heat-treated condition resulted from an improved abrasion resistance and not from a high inherent strength. This conclusion was also supported by other evidence. After heat treatment, the glass-ceramic was obviously hard and, in general, resisted scratching by materials with hardness less than 9 on the Moh's hardness scale.

Results of the study were summarized and several conclusions reached.

1. For a load duration of 0.82 seconds the wet strength of the particular composition studied was about 27,000 psi in the abraded condition after complete heat treatment and conversion to ceramic as compared with about 11,000 psi in the glassy as-formed state. In the unabraded (pristine) condition, the strength in the glassy state was greater than 80,000 psi, and after heat treatment it was about 38,000 psi. The heat-treated glass-ceramic is thus stronger than glass when both have been subjected to the same moderate abrasion but weaker when both are unabraded.

2. The static fatigue behavior of the glass-ceramic in all stages of treatment was very similar to that for ordinary soda-lime glass. The ratio of the 0.82-second strength to the 0.012-second strength was about 0.80 compared to a typical value of 0.78 for glass.

3. The increase in strength and abrasion resistance was gradual throughout the heat treatment process, beginning at the nucleation temperature (600°C) and continuing until the crystallization process was completed (900°C).

4. The development of optimum mechanical properties was not highly dependent on the detailed heating schedule above the nucleation temperature.

Crystallization of a Lead Metaniobate from a Glass. By R. C. Anderson, General Electric Research Lab. The objective of this work was to *(1)* formulate a glass from which ferroelectric crystals could be crystallized, *(2)* study its crystallization behavior, and *(3)* measure the dielectric properties of the resulting crystallized glass materials. Preliminary trials indicated that a glass could be formed in the PbO-Nb_2O_5-SiO_2-Al_2O_3 system.

Glass formation was studied using PbO, Nb_2O_5, SiO_2, and Al_2O_3 formulations. $PbNb_2O_6$ was identified as the primary crystallization product in glass films after heat treatment. Fifty-seven weight per cent orthorhombic $PbNb_2O_6$ was crystallized from one composition by controlled cooling of the melt. K and tan δ values were measured for crystal-glass composites.

At least three distinct crystalline phases were present in the samples formed by cooling from a melt. They were rhombohedral and orthorhombic $PbNb_2O_6$, and one or more secondary phases.

The rhombohedral phases usually crystallized as dendrite-like structures whose main stems were usually discontinuous. Each stem was formed by a repetitive arrangement of primary branches which cut across it at some given angle.

The orthorhombic phase occurred in three crystal types. During slow cooling from the melt, its tetragonal ancestor grew in bundles of long, parallel needles. Cross-sections of these bundles showed block-type growth similar to that exhibited by sections through the c-axis of fused mullite crystals. Rapid cooling produced a series of mosaic blocks. Each block was filled with dendritic needles. Rapid cooling to 1150°C followed by slow cooling below 1150°C resulted in crystallization of a mass of rounded grains which were aligned roughly in rows and columns.

The secondary phase(s) developed as lath-shaped crystals in the rhombohedral-glass matrix and appeared to precede the $PbNb_2O_6$ crystals in the sequence of formation. When a relatively low-opacity growth appeared in the orthorhombic needle bundles, it was interwoven, indicating formation after the $PbNb_2O_6$ crystals. This second phase(s) seemed to have formed above 1150°C.

It was suspected that a transformation from orthorhombic to rhombohedral $PbNb_2O_6$ might have caused washing out of the dielectric constant and dissipation factor maxima found on cooling certain samples. However, X-ray analysis of one sample before and after testing revealed no significant changes. A plausible explanation may be that interfacial polarization or trapping of electrons in high-energy positions occurrred as the result of rapid cooling. Such electrons would be provided with thermal energy on heating and thus be able to migrate to positions of greater stability. Electron migration would provide a false rise in dielectric constant and dissipation factor only on heating.

An Unusually Refractory Partially Crystalline Vanadia-Silica Glass. By S. D. Brown and S. S. Kistler, University of Utah. During investigations of the devitrification behavior of certain high-silica glasses, the authors prepared a series of partially crystalline vanadia-silica

glasses that were unexpectedly refractory. Compositions between $V^{+4}/100\ Si^{+4}$ ratios of 0.3 and about 1.5 gave blue glasses; the higher the vanadia content, the darker the glass. Some of the glasses with ratios near 1.5 were opaque and essentially black. As the vanadia content was increased toward ratios of 5, a definite brown color was noticed in thin sections.

Crystallinity was often observed in the glass with the naked eye. An X-ray diffraction pattern for a specimen with $V^{+4}/100\ Si^{+4} \cong 0.50$ indicated that the specimen consisted of crystalline regions in a vitreous matrix. A few of the lines in the X-ray pattern were recognized as those of α-critobalite, but there were a number of lines that were not characteristic of any known crystal.

The viscosity of the glass seemed unusually high. Fibers of the glass could not be drawn in flames that were successfully used to make fused silica fibers. The surface of each specimen exposed to the flames became glazed, but the effects of the heating did not seem to penetrate to the specimen interior. When heated in the flames, specimens of the glass glowed a dull red-orange in contrast to the bright white light emitted by fused silica. When the glass was heated 30-60 minutes at about 1800°C to 2000°C in the chamber of an induction furnace, evidence of extensive flow comparable to that observed with fused silica was noted. In this connection, Dr. Pincus of General Electric has found that the fluidity of such vanadia-silica glass, when melted in quantity, appears to be normal for fused silica.

Session II, Chemical and Structural Aspects—Clarence L. Babcock, Owens-Illinois Glass Co., Chairman

Conditions of Glass Formation Among Simple Compounds. By W. A. Weyl, College of Mineral Industries, Pennsylvania State University.* Glass formation may be understood only on the basis of a dynamic approach to the structures of liquids, which can be described by a scheme using a ternary diagram whose corners represent three extreme models of liquids:

1. *The Bernal liquid* has a structure which resembles closely that of an ideal crystal.
2. *The Frenkel liquid* is characterized by the presence of temporary ionic clusters and fluctuating fissures.
3. *The Stewart liquid* consists of clusters or molecules (polymers, chains) which have a long lifetime compared with the temporary ionic clusters which characterize the Frenkel liquid.

These idealized extreme models of liquids make it possible to catalogue the structures of glasses and plot structural changes with temperature and composition.

Thermodynamics cannot distinguish among the three types of liquids because the thermodynamics parameters cannot differentiate between a statistical distribution of internuclear distances and forces and a disproportionation of all distances and forces into smaller and larger ones. The difference between the orientable, glass-forming liquid of the Stewart type and the fissured liquid of the Frenkel type lies in the length of time of existence of the aggregates or clusters, and time is not used as a factor in thermodynamic treatments.

In spite of modern advances in the concept of chemical binding forces, one still finds scientists who use the bond strength as a parameter which is supposed to control mobility, *e.g.*, viscous flow and nucleation. There is no connection between bond energies and viscosity or the rates of nucleation. B_2O_3 and SiO_2 have similar bond energies but differ in their viscosities by nearly twelve orders of magnitude. Also, vitreous silica nucleates readily, but vitreous B_2O_3 does not. The bond energy of the Se-Se bond is less than that of the S-S bond, but selenium forms a stable glass which does not nucleate easily, whereas vitreous sulfur crystallizes within a few hours at ordinary temperature. These two glasses have identical structures, consisting of S_x and Se_x chains.

The activation energy of flow processes or solid state reactions is determined by the energy which is required for a partial, temporary unscreening of atomic cores, and this energy is not related in a simple fashion to the bond energy of atoms or to the field strength of ions.

Crystal Orientation as Influenced by Platinum Nucleation, By Guy E. Rindone, College of Mineral Industries, Pennsylvania State University. In normal devitrification processes, crystallization starts at a few sites on the surface of glass, leading to the growth of a relatively small number of crystals to large sizes. Studies of crystallization processes in lithium silicate glasses have revealed that the crystals which form under such conditions show a high degree of orientation with respect to the surface of the glass. It has been found, further, that the degree of orientation can be influenced drastically by introducing platinum nuclei into the glass.

This paper described experiments in which a lithium silicate glass had been nucleated with platinum in varying concentrations, crystallized for various times at 600°C, and then studied for the degree or orientation at the surface and at different depths below the surface. Lithium disilicate crystals which formed during the devitrification of lithium silicate glass showed a preferred orientation with the 002 plane parallel to the glass surface. This orientation persisted to great depths in glasses which had undergone prolonged heating at 600°C. The introduction of platinum nuclei into the glass during melting greatly decreased this tendency toward orientation at the surface and completely eliminated it several microns beneath the surface.

A maximum in orientation was found to occur at depths of 1 to 3 microns beneath the original crystallized surface, except after prolonged heat treatment at 600°C when the greatest degree occurred at the surface.

Explanations were offered for these observations based on the structure of the lithium silicate glass and the size and structure of the platinum nuclei.

(*Continued on page* 406)

*See The Glass Industry, *41* (8) 429, (9) 487, (10) 549, (11) 620, (12) 687, *42* (1) 23, (2) 76, (3) 123, and (4) 194.

Trouble-Shooting Metal-Mesh Belts In Glass Manufacturing

by John B. Hanson,
The Cambridge Wire Cloth Company, Cambridge, Maryland

With the proper installation and maintenance procedures, metal-mesh belts used in the glass industry for such applications as annealing, decorating, and transfer, will operate for years of satisfactory and trouble-free life. However, like any piece of mechanical equipment, troubles can occur. Most of these can be easily corrected. The following table has been prepared to provide some idea of what to look for when certain types of difficulty occur. Many of these "clues" are so obvious that you would undoubtedly detect them yourself, but others are somewhat unusual and may crop up only on rare occasions and under certain operating conditions. Nonetheless, a careful study of these suggestions and perhaps a filing of these pages for future reference may save you considerable trouble and downtime, should you experience one or another type of difficulty in your operations.

Each of these conditions has been specifically encountered in one plant or another over a period of years, and it is hoped that this check list will provide you with fairly complete advice on corrective measures.

—Ed.

ERRATIC BELT TRAVEL

Possible Cause	Possible Correction
Excess tension on belt take-ups, take-up on opposite sides of belt not equally weighted.	Check all rolls for proper alignment. Reduce take-up tension to zero. Start belt; add only enough tension required to prevent slippage on drive pulley.
Faulty oven components.	"Frozen" or excessively worn rollers and bearings inside the oven should be freed or replaced. For best results, use anti-friction bearings mounted *outside* the oven.
Adjusting roll out of alignment.	Be sure adjusting rolls on take-up are properly aligned with relation to drive pulley.
Faulty support rollers.	Install horizontally movable support rollers beneath belt. Adjust alternate rollers in opposite directions.
Faulty thermocouples cause uneven heating.	Check for proper thermocouple operation.
Attempting to control tracking with adjustment of end rolls.	Install adjustable bottom rolls. Maintain constant alignment of end roll.

Incomplete installation of return rollers.	Be sure all rollers are properly installed in place before operating lehr.
Excess number of vertical guide rolls and uncovered location of same on return side of belt.	Remove every other vertical guide roll. Relocate balance so the vertical guides are located midway between carrying rolls on return side of belt.
Misalignment of terminal pulleys.	Be sure terminal pulleys are level and parallel.
Nonuniform lehr temperature.	Insulate to provide uniform temperature.

BELT SLIPPAGE

Possible Cause	Possible Correction
Inadequate material used in bearings at take-up rolls or belt guides.	Be sure bearing material will not bind because of uneven pressure. Antifriction material recommended.
Bronze bearings in tail pulley.	Elimination of bronze bearings and proper pulley alignment—install antifriction bearings.

BELT EDGES TURNING UP

Possible Cause	Possible Correction
Insufficient clearance between belt edges and side rails of the lehr.	Be sure that any belt installed is designed for the specific lehr in which it is to be used. Allow sufficient clearance between belt and side rails on initial installation.
Warped side rails on lehr due to uneven heat.	Check burners for proper distribution of heat. Reduce belt width to compensate for reduced lehr width.

EXCESSIVE EDGE WEAR

Possible Cause	Possible Correction
Frozen vertical rollers.	Check all rollers to make sure they turn freely and easily.
Warped side rails.	Replace side rails or cut belt width to compensate for reduced lehr width due to rail warpage.
Faulty burners concentrate heat on belt edges.	Adjust or replace burners so that belt is heated uniformly across entire width.
Excessive lehr temperature, overloading of belt.	Increase alloy strength, control lehr temperature.

BELT HUMPING

Possible Cause	Possible Correction
Uneven distribution of heat within lehr.	Be sure access panels to lehr are closed during operation to prevent access of cool air causing uneven heat distribution.
Improper heat control.	Adjust heat controls so as not to overheat the belt. Be sure proper heat is uniformly distributed.
Roller misaligned.	Remove belt from lehr and check to see that *all* rollers are properly aligned.

BELT VIBRATION

Possible Cause	Possible Correction
Worn sprocket or chain on drive.	Install herringbone or helical-type gear reducer. Replace worn components.

DEFORMATION OF SPIRALS

Possible Cause	Possible Correction
Undersized drive pulley and excessive pressure on press roller.	Install larger drive roll and provide for 220-degree wrap.

EXCESSIVE BELT WEAR

Possible Cause	Possible Correction
Friction.	Install wear strips on supporting rails. Use maple, plastics or metal. If metal is used, be sure the metal is harder than the alloy used in the belt.

SHORT BELT LIFE

Possible Cause	Possible Correction
Excessive oxidation.	Specify low-chromium alloy wire instead of high-carbon steel.

HIGH BELT COST

Possible Cause	Possible Correction
Incorrect alloy selection.	Specify low-chromium alloy instead of high-carbon steel for longer belt life. Consider lighter belt construction with low-chromium alloy.

BELT ELONGATION

Possible Cause	Possible Correction
Excessive lehr temperature.	Careful control of lehr temperature for annealing and alloy selected for belt construction.
Driving from discharge end.	Change drive to charge end to reduce tension.

BELT PULLING AHEAD ON ONE SIDE

Possible Cause	Possible Correction
Misalignment of lehr sections.	Proper alignment of lehr frame and jacket.

BELT DISTORTION

Possible Cause	Possible Correction
Overloading.	Revise belt specifications to handle load requirements.
Misalignment of supporting rolls and terminal pulleys.	Be sure supporting rolls and terminal pulleys are level and parallel.
Incorrect drive, drive pulley too small in diameter, lack of wear strips.	Locate drive properly, increase dimension of drive pulley, install wear strips.

BELT TRACKING

Possible Cause	Possible Correction
Stretching due to nonuniform loading requirements.	Heavier belt construction, stronger alloy.

MARKING OF WARE

Possible Cause	Possible Correction
Lehr temperature close to melting point of ware.	Coat belting with protective material to prevent transfer of heat scale to ware.

CROSS RODS BREAKING

Possible Cause	Possible Correction
Obstructions in lehr cause flexing of belt.	Remove obstructions and realign supporting rolls.

EDGES BREAKING

Possible Cause	Possible Correction
Hot spots in lehr.	General repair of lehr to eliminate hot spots; consideration of higher alloy wire in belt to withstand uneven temperatures.

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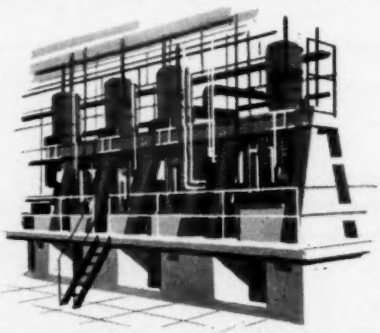

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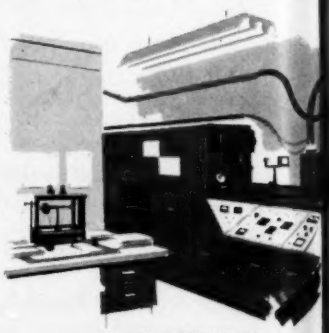

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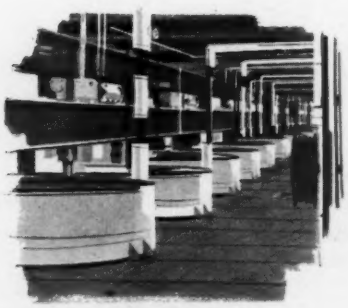

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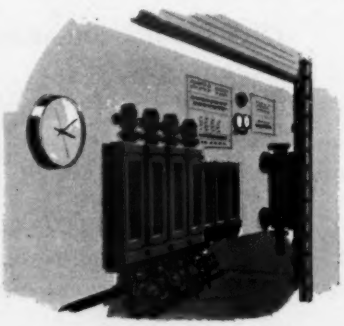

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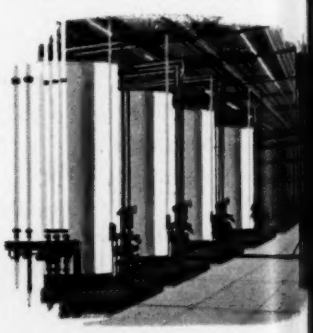

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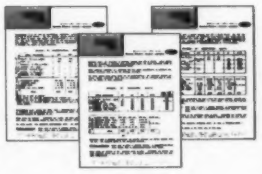

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Bibliography on Glass Structure*

PART XII

311. Webster Capps

"Viscosity of Glass," J. Colloid Sci., 7, 334-42 (1952); Ceram. Abstr. 1956: 93g.

Methods of measuring the viscosity of glass, and the relationship between the data obtained and the structure of the glass are reviewed. The nature of the interionic binding and the ion size at various temperatures is discussed for some binary alkali silicates.

312. Frida Oberlies and Adolf Dietzel

"Structure of Silica Glass," Glastech. Ber., 30, 37-42 (1952); C. A. 51: 7673e.

A re-examination of Warren's x-ray work. Calculation of distribution curves indicates a type of order similar to β cristobalite, viz. 6 membered rings of SiO_4 some of which are open. The order is much higher than in Zachariasen model. Also concluded that individual tetrahedra of SiO_4 are distorted.

313. Giuseppe Bifani

"Chemical Resistance of Glass," Atti Congr. Intern. Vetro, 3rd Congr., Venice, 1953, 349-53 (in Italian); Ceram. Abstr. 1957: 36d.

A review of the modern theories on the structure of glass. A method of calculating the stoichiometric relations between constituents in the glass to obtain high chemical resistance is also discussed.

314. Kentaro Takahashi

"Thermal Expansion Coefficients and the Structure of Glass. I.," J. Soc. Glass Technol., 37, 3-7 N (1953); Ceram. Abstr. 1956: 33g.

315. Ryosuke Yokota

"Color Centers of Quartz, Fused Quartz, Alkali Silicate, and Borate Glasses," Atti Congr. Intern. Vetro, 3rd Congr., Venice, 1953, 210-17; Ceram. Abstr. 1956: 236g.

By comparing the x-ray absorption bands of fused quartz made under various conditions, quartz crystals and silicate glasses Yokota concludes that glass lacks the long range order of crystals and that the crystallite theory of glass is therefore excluded.

316. L. Ainsworth

"Diamond Pyramid Hardness of Glass in Relation to the Strength and Structure of Glass. I. Investigation of the Diamond Pyramid Hardness Test Applied to Glass. II. Silicate Glasses. III. Structure of Borosilicate Glasses," J. Soc. Technol., 38, 479-500 T, 501-35 T, 536-47 T (1954); Ceram. Abstr. 1956: 209i.

Ainsworth shows that the diamond pyramid hardness test provides a measure of the yield point of glass independent of Griffith flaws. The method is extremely sensitive and the measurement is independent of the load provided it is less than that needed to cause fracture in the glass.

Fused silica is found to have a higer yield point than any other glass investigated. Alkali oxide additions initially decrease the bond strength, but later there is a slight increase followed by a further decrease in strength. Sodium and potassium combinations yield stronger glasses than each individually.

The diamond pyramid number has its highest value when the sum of the modifying ions is about 33 mol percent. At this composition, on the average, one corner Si-O-Si link from each of the tetrahedral structural building units is broken. In the case of potash-silica glasses the maximum occurs at 18 mole percent K_2O because the large potassium ion cannot readily be accommodated in the small interstices of the silica network. The bond strength as determined by this method for several other oxides is discussed and the order of their strength related to the charge on the cation, its size, and its method of bonding in the structure.

The hardness test was also applied to borosilicate glasses and attempts to relate data to the structure of the glasses as presently detailed were unsuccessful. The B_2O_3 anomaly is discussed and an explanation advanced to reconcile present results with theory.

317. O. Borgen, K. Grjotheim, and J. Krogh-Moe

"X-ray Determination of Glass Structures," Kgl. Norske Videnskab. Selskabs, Forh. 27 (17), 86-93 (1954). (In English.)

The radial distribution curves obtained by x-ray diffraction are often used to determine coordination numbers. Some of the sources of errors affecting the determination of these experimental coordination numbers are discussed. It is concluded that coordination numbers determined by the present x-ray technique should be taken with some reservation. 3 figures, 12 references.

318. K. Grjotheim and J. Krogh-Moe

"Structural Explanation of the Boron Oxide Anomaly," Kgl. Norske Videnskab. Selskabs, Forh. 27 (18), 94-99 (1954); C. A. 50: 9704g.

It is proposed that the boron anomaly is due to a change of the configuration around boron from a larger coordination number in boron oxide glass to a smaller coordination number in the alkali borate glasses. The theory is found to be consistent with various physical properties of these systems. The proposed explanation is not contradicted by x-ray investigations on borate glasses. 1 figure, 13 references.

319. M. A. Aglan and H. Moore

"Colors of Cobalt in Glass," J. Soc. Glass Technol., 39, 351-84 T (1955); Ceram. Abstr. 1957: 158f.

The absorption bands in the visible spectrum of

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cobalt contained in various glasses were determined by spectral photometric methods. Magnetic measurements were also made on many different types of glass containing cobalt. These tests all showed that cobalt was present as divalent ions. It was concluded that pink colored cobalt glasses were obtained when the divalent ion was in sixfold coordination with oxygen, the blue color when in four-fold coordination with oxygen. Green and yellow glasses are obtained when halogens present cause new absorption bands. The blue color obtained in acidified cobalt chloride solution does not result from the same cause as that given by cobalt in glasses. In the case of solutions the color is due to the presence of $CoCl_4^{2-}$ ions.

320. A. N. Dauval'ter

"Structure of Glass," Steklo i Keram., 12, No. 3, 12-17 (1955); Ceram. Abstr. 1956: 93j.

The properties of glass such as color opacity viscosity, etc. are explained in atomistic terms.

321. Emil Deeg and Adolf Dietzel

"Cause of the Anomalous Mechanical Properties of Glass Fibers," Glastech. Ber., 28, 221-32 (1955); Ceram. Abstr. 1956: 50h.

The lower density of glass fibers is due to their more open structure or lesser degree of network formation. Their greater strength and better elastic properties are due to the more isotropic nature of their formation, in which there are fewer stresses than in bulk material.

322. Maurice L. Huggins

"The Structon Theory of Glasses and Solutions," Bull. Chem. Soc., Japan, 28, 606-13 (1955). (In English.) C. A. 50: 13547e.

Structure type is described by the assemblage of close neighbors around a given kind of atom. Discontinuities in properties may frequently indicate changes in the types of structons present. Theory applied to sodium silicate glasses and liquid solutions containing strong hydrogen bonds between molecules.

323. A. A. Lebedev, N. A. Toropov, V. P. Barzakovskii, and A. A. Appen, Ed.

The Structure of Glass, Symposium, Leningrad, November 23-27 (1953), Acad. Sci. U.S.S.R., Leningrad-Moscow, 1955; C. A. 50: 11631e.

324. Evelyn C. Marboe and W. A. Weyl

"Atomistic Interpretation of the Effect of the Composition on the Viscosity of Glass," J. Soc. Glass Technol., 39, 16-36 T (1955); Ceram. Abstr. 1956: 236d.

In order to understand the viscous flow of glasses the interaction of atoms across considerable distances must be taken into consideration. This implies that the properties of matter are sensitive to the volume under stress. Viscosity and strength should increase as the volume under test becomes too small for the interaction of atoms across large distances.

325. Karl Plieth, Ellen Reuber, and Iwan N. Stranski

"Structural Investigations of an Arsenic Glass. Fourier Analysis," Z. Anorg. u. Allgem. Chem., 280, 205-10 (1955); C. A. 50: 2234a.

326. Abd-El-Moneim Abou-El-Azm

"Spectrophotometric and Magnetic Studies of Glasses Containing Iron in Relation to Their Structure. I. Forms in Which Iron Exists in Glass. II. The Alkali-Silica Glasses. III. Alkali-Silica Glasses Containing the Oxides of Certain Divalent, Trivalent, and Tetravalent Metals. IV. Borate, Cabal, Phosphate Glasses. V. Applicability of the Color and Magnetic Measurements to the Study of the States of Iron in Glass, the Structure of Glass, and the Roles Played by Various 'Decolorizers'," J. Soc. Glass Technol., 38, 101-45T, 146-96T, 197-243T, 244-70T, 271-76T (1954); Ceram. Abstr. 1956: 53d.

Magnetic and color analysis indicate that iron exists in glass in at least five forms. The blue color is due to ferrous iron, ferric oxide however can contribute to a brown color and is present as colloidal dispersion. A colloidal magnetite gives a gray color whereas FeO_4 tetrahedra do not give any color at all. Iron may also exist as an alkali ferrite but is only found in high alkaline glasses. The paper discusses the relationship between the chemistry of the glass and the occurrence of these various forms of iron.

327. E. A. Porai-Koshits, S. P. Zhdanov, and D. I. Levin

"Relation Between Structure and Opalescence in Sodium Borosilicate Glasses. III. Comparative Structural Investigation of the Glasses and Their Porous Products of Alkali Removal," Izvest. Akad. Nauk S.S.S.R., Otdel, Khim, Nauk, 1955, No. 3, 395-402; Ceram. Abstr. 1956: 113h.

The porous product made by leeching certain opalescence sodium borosilicate glasses is made possible by the presence of separate silica and borate phases.

328. S. P. Zhdanov, E. A. Porai-Koshits, and D. I. Levin

"Relation Between Structure and Opalescence in Sodium Borosilicate Glass. II. Structure of Porous Glasses," Izvest. Akad. Nauk S.S.S.R., Otdel, Khim, Nauk, 1955, 197-207; Ceram. Abstr. 1956: 52f.

This investigation showed that the glass contained two structures namely a coarse framework of the basic siliceous shell and a fine porous structure of highly dispersed silica inside the channels of the framework. The channels in the coarse skeleton may exceed 1000 angstrom units compared with 80 to 160 angstrom units in transparent glass. The pores of the fine structure do not exceed 20 to 40 angstroms.

329. Herbert Schonborn

"Equilibrium Adjustments in Glasses Between Room Temperature and 100°C," Silikattech., 6, No. 9, 367-71 (1955); Ceram. Abstr. 1956: 72h.

The structure of some silicate glasses between 0° and 100°C was frozen in by quenching and changes in density and thermal expansion were determined.

(To be continued in August)

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FOR OVER 60 YEARS THE GLASS INDUSTRY'S PARTNER IN PROGRESS

One manufacturer's account of current trends in the processing and application of fiber glass reinforced materials.

Recent Developments In FIBER GLASS REINFORCEMENT

by William H. Chadbourne

President, Fiberfil, Inc., Warsaw, Ind.

The concept of using one material to reinforce another has long been an accepted practice, used most successfully in materials such as concrete and thermosetting plastics. At the same time, many attempts have been made to improve the physical properties of thermoplastics by the incorporation of reinforcing materials like fiber glass.

Now on the market are a wide variety of compounds based on materials such as nylon, polystyrene, acrylonitrile and polycarbonate, all of which are reinforced with fiber glass. The combination of the reinforcing agent (fiber glass) and the plastic yields a third material with properties that are both substantially improved over the original plastic and, in some cases, exhibit characteristics that are quite different. For example, the impact strength of all thermoplastics will drop to a more or less alarming degree with a decrease in temperature. This is true of plain polystyrene and nylon, but when combined with fiber glass, both materials show increased impact strength. To illustrate this point, a comparison of Izod impact strength with unfilled plastics may be seen in Table I.* It is interesting to note that, while some other materials have higher impacts at room temperature, only the fiber glass compounds improve at –40°F.

Table I

IZOD IMPACT

	Ft. Lb./Sq. In.	
	Low Temperature –40°F	Room Temperature 73°F
Polystyrene (high-impact)	0.4-2.5	2-11
Polyethylene (low-density)	0.3-2.2	>16
Polypropylene	0.6	0.6-6.0
Nylon 6	0.6	1.0-3.6
Acrylonitrile (butadiene styrene)	0.7-2.0	0.7-12
Polyethylene (high-density)	0.9-1.8	1.5-12
Acetal	0.9	1.4-2.3
Polycarbonate	1.8	2.0
Reinforced Nylon G-10	4.0-6.0	3.3-5.5
Reinforced Polycarbonate G-50	4.0-5.0	3.5-5.0
Reinforced Acrylonitrile G-40	4.0-5.5	3.0-5.0
Reinforced Polystyrene G-31	4.5	4.0

*"G" numbers refer to Fiberfil, Inc., specifications.

While all physical properties are generally improved by the addition of fiber glass to the base resin, some properties stand out as particularly important. Among these are tensile strength and deformation under load. In Table II it will be seen that reinforced nylon G-1 carries almost twice the tensile strength of unreinforced nylon, while, a newer series, G-10 and G-13, carries almost three times that of the unfilled material. In fact, these latter grades are reaching well into the tensile levels of some fairly commonly used metals. Deformation under load for thermoplastics is normally taken at 2000 psi. At 2000 psi fiber glass reinforced materials show so little deformation that loading was doubled to 4000 psi to obtain a readable level (Table III). These three charts comparing mechanical properties demonstrate the general trend of improvements characteristic of these materials.

Table II

TENSILE STRENGTH AT 73°F

	PSI
Phenolics	7000–8000
Polycarbonate	8500–9500
Acetal	10,000
Polyester Premix (gunk)	5000–10,000
Nylon 6 and 66	7000–12,000
Reinforced Polystyrene G-31	14,300
Reinforced Acrylonitrile G-40	20,000
Reinforced Nylon G-1, G-2, G-3	19,000–22,000
Aluminum Alloys (cast)	18,000–28,000
Reinforced Nylon G-10, G-13	30,000
Magnesium Alloys (cast)	22,000–40,000
Zinc Alloys (cast)	41,000–47,000

Table III

DEFORMATION UNDER LOAD at 4000 PSI, 122°F

	Per Cent
Reinforced Polycarbonate G-50	0.10
Reinforced Acrylonitrile G-40	0.28
Polycarbonate	0.28
Reinforced Polystyrene G-32	0.35
Reinforced Nylon Nylafil G-1 (MS)	0.40
Acetal	1.6
Polystyrene (general purpose)	1.9
Nylon 66	2.5
Nylon 610	3.9
Nylon 6	4.9

Unfilled thermoplastics have long been plagued by dimensional instability in the more demanding mechanical applications. Characteristics such as moisture susceptibility resulting in dimensional change, coefficient of linear thermal expansion, and residual release of strains have eliminated mechanical-type thermoplastics from many applications where they were otherwise ideal. Glass reinforcement Table IV reduces the coefficient of linear thermal expansion from 1/5 to 1/7 of previous levels. The reinforcement makes a proportionate improvement in moisture-sensitive materials which are also much more stabilized against residual stress release. The combination of these factors results in a product that can be used under close tolerance conditions where a wide latitude of environmental conditions exist. It is in these fields where heretofore metals have been preeminent that fiber glass reinforced materials offer their most interesting design potential. Furthermore, the chemical and electrical characteristics of the various

Table IV

COEFFICIENT OF LINEAR THERMAL EXPANSION
(10^{-6} in./in./°F)

Nylons	58.5
Acetal	45.
Polycarbonate	39.
Phenolics (general purpose)	20.8
Zinc Alloys (cast)	15.2
Magnesium Alloys (cast)	15.
Polyester Premix (gunk)	14.
Reinforced Nylon G-2	13.3
Reinforced Nylon G-3	12.5
Aluminum Alloys (cast)	12.5
Copper and its Alloys	10.4
Reinforced Nylon G-10	9.0
Stainless Steel (cast)	8.4
Carbon Steel (cast)	8.3
Reinforced Polycarbonate G-50	7.0

compounds are quite similar to those of the nonreinforced base materials. For example, nylon maintains its lubricity and polycarbonate remains nonflammable.

Compounds

Reinforced Nylon

The standard nylon and fiber glass combinations, G-1, G-2, and G-3, are based on types 66, 610, and 6 nylons, respectively. In addition, there are a number of special compounds for specific applications and environmental conditions. Among these are an easier molding, better filling grade and a hydrolysis-resistant type particularly adaptable to hot water applications. (After 3 months in 180°F water it shows no significant degredation.) Where increased lubricity is required, *e. g.*, for cams and bearings, fiber glass reinforced nylon containing 5 per cent molybdenum disulphide has been found to be advantageous. For high environmental temperatures there is a heat-stabilized grade which would be well suited for intermittant service over a long period of time. (This material has been tested at 400°F for 100 hours and has shown a loss of only 10 per cent of its original properties.) More recent in development are the G-10, G-12, and G-13 series, the first of which is compared with unfilled type 66 nylon in Table V. These materials possess particularly high mechanical strength.

Table V

Property	Unfilled Nylon 66	Reinforced Nylon G-1	Reinforced Nylon G-10
Tensile Strength @ 73°F	11,800	q 19,100	30,000
Elongation @ 73°F	60	1.5	1.9
Flexural Modulus @ 73°F	4.1×10^5	9.8×10^5	18×10^5
Izod Impact @ 73°F	.9	2.5	3.3
@ −40°F	.6	3.0	4.0
Compressive Strength	.....	16,000	24,000
Flexural Strength	11,500	22,000	37,000
Rockwell Hardness	M 79	M 100	E 75
Deformation under Load 4000 PSI/Per Cent	2.54	0.6	0.4
Water Absorption 24 Hours/Per Cent	1.5	0.7	0.6
Specific Gravity	1.14	1.36	1.52
Heat Distortion Temperature 264 PSI	150°F	498°F	502°F

Fiber glass reinforced nylon has been widely used for such parts as gears, bearings, coil forms, bearing retainers and similar mechanical components. Other interesting applications have been in cams and thermostat parts which are subject to a wide temperature range. Plain nylon, because of its high coefficient of linear expansion, has been generally eliminated from bearing retainer applications. The reinforced nylons, however, are ideal because of their low expansion, and are rapidly becoming standard in this field (see Fig. 1).

Reinforced Polystyrene

While polystyrene is not generally considered to be a material suited for mechanical applications, the addition of fiber glass gives it some very interesting characteristics, including vastly improved mechanical properties and better dimensional stability. Reinforced polystyrenes are now being used for magnetic tape reels, housings and reinforcement members in the automotive industry, and spacers and gussets in the refrigeration industry.

Typical of the many applications for fiber glass and polystyrene compounds is the tape reel, shown in Fig. 2, which was originally produced in polystyrene or modified polystyrenes. However, as the electronics industry went into larger sizes and heat requirements rose, it was determined that the nonreinforced types tended to sag and lose their stiffness. In addition, the hubs cold-flowed and permitted locking on the tape deck spindles. Here the part is dry colored by the molder and shows uniform molding and dispersion throughout the piece.

Shown in Fig. 3 is an air conditioning blower wheel. This part was formerly made out of aluminum, but it has been found that aluminum sets up a resonant hum in the unit which carries itself into the house, creating a noisy and, hence, undesirable appliance. In an effort to overcome that problem and reduce costs, various

plastics were tried. While an injection molder blower wheel was found to be less expensive, it had one serious drawback. Its blades individually tended to flex at high speeds, thus reducing the volumetric output of the blower wheel. Therefore, it was decided to try fiber glass reinforcement, with the result that this disadvantage has been reduced by approximately 70 per cent. In addition, should ice form in the unit and the unit be turned on inadvertently during the wintertime, the reinforced polystyrene will stand considerable deflection, a good

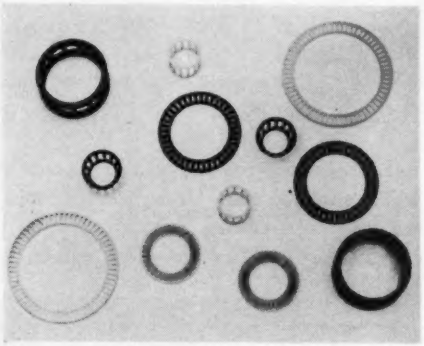


Fig. 1. Reinforced nylon bearing retainers.

illustration of how improved cold impact resistance can be a highly desirable characteristic.

The crash pad insert for one of the major automotive manufacturers is another application for which reinforced polystyrene has been found well suited. It is the largest injection molding ever used on an automobile and represents a considerable step forward in the field.

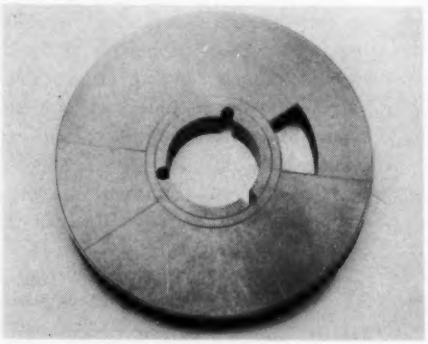


Fig. 2. Reinforced polystyrene tape reel.

This particular piece is molded on a 175-oz. injection molding machine in an 11,500-lb. tool. The cavity is fed by five hot runners spaced along the actual length of the part. It is interesting to note that the material has shown a high degree of ability to flow around a very substantial number of cores and obstructions. In this case, reinforced polystyrene was chosen because of its high order of stiffness and excellent dimensional stability. On a cost basis it affected a very considerable reduction over the metal stampings that it replaced. As can be seen in Fig. 4A and 4B, this crash pad consists of the molded reinforced polystyrene core. This core has urethane foamed in place in a matched metal mold, with a hot vinyl cover stretched over the urethane. This assembly is approximately 54 in. in length and 3 lb. in weight.

Reinforced Acrylonitrile

Two grades of fiber glass and acrylonitrile compound, just recently introduced show very promising characteristics. They have high mechanical properties and good solvent resistance. Table VI shows a comparison of physical properties between the filled and unfilled grades.

Reinforced Polycarbonate

Another recently developed compound is the new G-50 fiber glass reinforced polycarbonate. Polycarbonate is being rapidly accepted in the molding industry as a high-performance mechanical material. Reinforced poly-

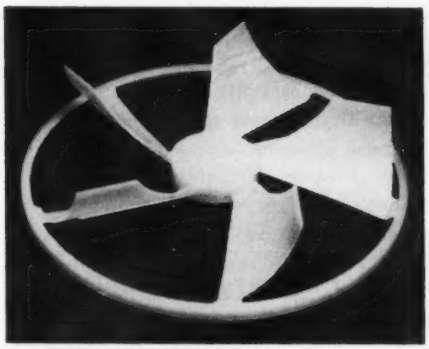


Fig. 3. Reinforced polystyrene air conditioning blower wheel.

carbonate is already fitting into those applications where the unfilled material has been inadequate from a mechanical or stability standpoint. The designer can also combine the many advantages of a glass-reinforced compound with the assurance that the material is, in regard to flammability, fully self-extinguishing. Furthermore, reinforced polycarbonates exhibit high mechanical strength and very low moisture absorption, making the G-50 grade, for example, well suited for high-humidity applications. Table VII gives comparative physicals, while Table VIII covers electrical properties.

Processing

Molding

Generally speaking, fiber glass reinforced compounds process in a manner similar to that of the corresponding nonreinforced materials. However, there are a few exceptions which can be noted to insure repeated production of good, uniform moldings. Cylinder temperatures

will be anywhere from 25° to 100° higher than normal, but it is important to remember that high melt temperatures are not the solution to filling an intricate cavity. Most important is the use of a heated mold. Temperatures should be controlled within a 5° range, and therefore, an accurate die heater is required.

If the cavity is not filling adequately, the temperature of the mold rather than that of the melt should be increased. Maximum machine pressure should be used in most instances. On most parts, only 60 to 70 per cent of rated machine capacity should be employed when processing fiber glass reinforced compounds. This will

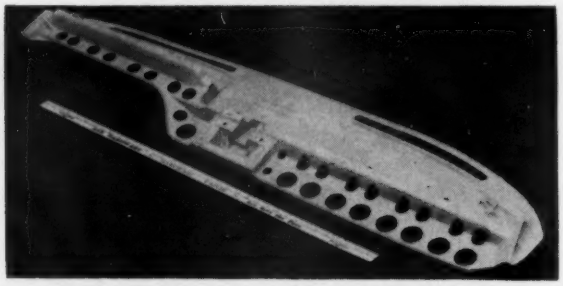


Fig. 4A. Reinforced polystyrene crash pad core.

result in greater uniformity and highest quality. Molds require more draft because the material does not have any elongation to speak of, and for this same reason, undercuts are not recommended. Regrind may be used in quantities up to 25 per cent, although it is recommended that the bed knife be backed away from the rotating blade as much as ¼ in., thus giving a coarse rather than a fine grind. A fine grind will result in a substantial reduction of fiber length which, in turn, will give lowered physical properties. Fiber glass reinforced materials will set up in the cavity anywhere from 10 to 30 per cent faster than will the same material unfilled. While the material tends to be more expensive, this considerable improvement in cycle time will reduce the total cost spread.

Table VI

Property	Unfilled Styrene Acrylonitrile	Reinforced Acrylonitrile G-40	G-41
Tensile Strength @ 73°F	11,000	20,000	15,000
Elongation @ 73°F	3.2	1.4	1.0
Modulus of Elasticity @ 73°F	5.2×10^5	15×10^5	10×10^5
Izod Impact @ 73°F	0.45	3.5	5.5
@ —40°F	.....	4.0	6.0
Compressive Strength	17,000	22,000	22,000
Flexural Strength	17,000	28,000	27,000
Rockwell Hardness	M 83	E 68	E 62
Deformation under Load 4000 PSI/Per Cent	.....	0.3	0.4
Water Absorption 24 Hours/Per Cent	0.23	0.15	0.15
Specific Gravity	1.07	1.35	1.37
Heat Distortion Temperature 264 psi	200°F	220°F	215°F

Table VII

Property	Unfilled Polycarbonate	Reinforced Polycarbonate G-50
Tensile Strength @ 73°F	9000	19,000
Elongation @ 73°F	60-100	1.4-2.0
Modulus of Elasticity @ 73°F	3.2	8.0-9.0
Izod Impact @ 73°F	2.8-2.0	2.0-5.0
Compressive Strength	11,000	19,000
Flexural Strength	12,000	26,000
Rockwell Hardness	M 70	M 95
Deformation under Load 4000 PSI/Per Cent	.3	.1
Water Absorption 24 Hours/Per Cent	0.3	.03-.10
Specific Gravity	1.2	1.4-1.52
Heat Distortion Temperature 264 PSI	280	300

Fabrication

While it is accepted practice in the plastics industry to fabricate prototype parts from rod or sheet stock it is generally recommended that this practice not be used for prototype work on fiber glass reinforced com

Fig. 4B. Finished crash pad with vinyl cover.

pounds. Because the fiber glass is the load-bearing member, any extensive machining of a piece of stock must inevitably cut through the reinforcing monofilaments. Thus, the strength and other properties of the material are often materially reduced and an unfavorable test is the net result. Wherever possible a prototype single cavity mold should be produced. In the case of extremely simple parts such as a disc or washer, machining is

(*Continued on page* 410)

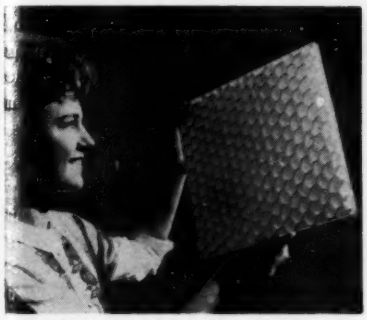
Table VIII

Property	Unfilled Polycarbonate	Reinforced Polycarbonate G-50
Arc Resistance	10 Seconds	7 Seconds
Dielectric Strength		
Short Time	400 V/Mil	482 V/Mil
Step-by-Step	364 V/Mil	422 V/Mil
Volume Resistivity, Ohm/CM	2.0×10^{16}	1.4×10^{15}
Dielectric Constant		
60 Cycles	3.17	3.8
10^3 Cycles	3.02	3.8
10^6 Cycles	2.96	3.7
Dissipation (power factor)		
60 Cycles	0.0009	0.0030
10^3 Cycles	0.0011	0.0022
10^6 Cycles	0.01	0.008

Applications...

REINFORCED PLASTIC LIFEBOATS have been installed in the S.S. Mormack's newest ships. Fire-retardant polyester resins are combined with fiber glass in the construction. Approved by the U. S. Coast Guard, the boats are 30 ft. long and have a 78-person capacity. *Lunn Laminates.*
Reader Service Card: Circle No. 50

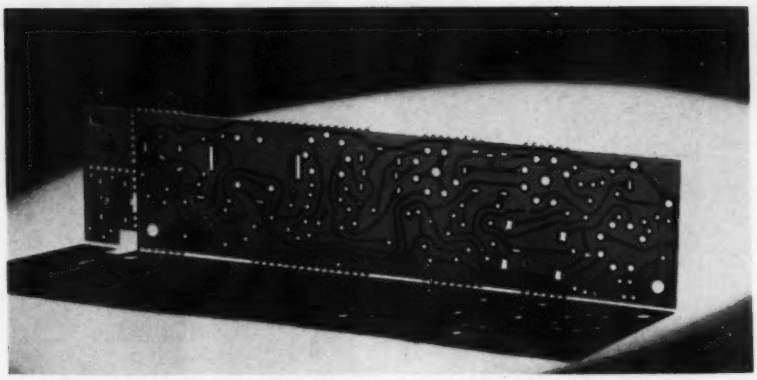
FIBER GLASS REINFORCED PLASTIC SHEETS joined by a rag bond honeycomb core are now being used for the housing of a laundromat in Manitou Beach, Mich. Known as "Plastifiber," the product has previously been used only for patios. The honeycomb construction makes these panels notably strong and they never



Honeycomb construction can be seen in this section of building panel.

require maintenance or painting. An air space between the two sheets provides a high insulating value. Translucent, they afford privacy while admitting natural light. *Plastifiber & Chemicals.*
Reader Service Card: Circle No. 51

SOUND CONTROL BLANKETS composed of 96- by 1½-in thick batts of fiber glass insulation are claimed to be the first economical system for reducing room-to-room transmission of sound. The blankets are faced with an impervious septum and installed in pairs, back to back, between studs before dry wall or lath and plaster is applied. When used in homes, motels, apartments, and other light construction, they reduce sound level from one room to another 83 per cent compared to conventional walls built with 2- by 4-ft. framing members. *Owens-Corning Fiberglas Corp.*
Reader Service Card: Circle No. 52



Shown here is a fiber glass circuit pattern for car radio etched and punched.

IMPROVED WEATHER RESISTANCE is claimed for a fiber glass reinforced panel produced under a new chemical formula. The panel, called "XR1000" has been shown to resist eroding effects of the elements five times better than conventional fiber glass panels. The retention of light transmission properties is also improved five-fold, and color is retained approximately 2-1/3 times better. *Barclite Corp. of America.*
Reader Service Card: Circle No. 53

NEW LINE OF GOLF CLUBS features a shaft made entirely of fiber glass. Weatherproof, the new shaft needs no maintenance other than an occasional wiping with a damp cloth. It is also said to add distance and give more positive control. *Burke Golf Sales.*
Reader Service Card: Circle No. 54

New fiber glass shaft has no steel core and no metal reinforcement.

REINFORCED ELECTRICAL LAMINATE for printed circuitry is now on the market at a price competitive with paper base phenolic circuit boards. The new copper-clad laminate provides the high tensile, flexural, and impact strength of fiber glass reinforced plastic with low loss factors, increased insulation resistance, and low moisture absorption. Called "Cimclad," the laminate is easy to process and will cold punch well at room temperature. It virtually eliminates printed circuit board breakage and, from the standpoint of flamability, is self-extinguishing. *The Cincinnati Milling Machine Co.*
Reader Service Card: Circle No. 55

WRIST WATCH MOVEMENTS made of fiber glass filled diallyl phthalate compound are being used by Bulova Watch Co. in their "Accutron" electronic timepiece. The compound, called "Dapon," produces parts that are tough, flexible, and environmentally immune, insuring proper functioning and long life. *Food Machinery and Chemical Corp.*
Reader Service Card: Circle No. 56

CATALOGS RECEIVED

Handbook of fibrous materials (495 pages). Air Force report consolidating data on fibrous materials research. Includes information on basic design, sewability, friction, abrasion and weather resistance, porosity and air permeability, temperature properties, and chemical resistance of different yarns, cords, webbings, and fabrics. *U. S. Department of Commerce.*
Reader Service Card: Circle No. 57

NEWS
IN THE GLASS INDUSTRY

James H. Price

Owens-Illinois Glass Co.

JAMES H. PRICE named manager of the new glass container plant at Brockport, N.Y. . . . Construction of a glass container plant near Tracy, Calif., begun May 1, will be completed early in 1962.

Mason Instrument Co., Inc.

WILLIAM C. CHASE named sales manager for photoelectric controls and radiation pyrometer controllers.

Glass Container Industry Research Corp.

Now representing 20 glass container companies in the U. S., met at White Sulphur Springs, W. Va., May 24. DR. A. L. JOHNSON, president and director, presented the annual report on GCIR research projects. All officers were re-elected for a second term.

Houze Glass Corp.

WILLIAM M. TEMPLE appointed manager of government sales with headquarters in Washington, D.C.

Tariff Commission Rules

The TC has recommended to President Kennedy that the tariff on imports of crown, cylinder, and sheet glass be hiked to protect the U. S. glass industry. Under law, the President must accept, reject, or modify the recommendation this month.

In a separate action, the Commission refused to ask President Kennedy to raise duties on imported rolled glass.

Dr. Howard Steinberg

U. S. Borax Research Corp.

DR. HOWARD STEINBERG appointed director of chemical research.

Corning Glass Works

DR. JOHN F. G. HICKS named associate director of Battelle Memorial Institute. Formerly vice-president of the Glass Works and vice-president and technical

Dr. John F. G. Hicks

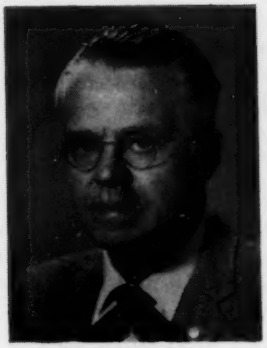
director of Corning Glass International, he is also a member of the American Ceramic Society and the Society of Glass Technology.

Colorado Fuel & Iron Corp.

LEONARD C. ROSE elected executive vice-president, and RUDOLF SMITH, executive vice-president, operations.

Iowa State Names Department Head

DR. DAVID W. WILDER appointed chairman of the department of ceramic engineering, effective July 1. He succeeds PROF. C. M. DODD who will remain on the University teaching staff.



Francis W. Glaze

Chemist Receives Award

FRANCIS W. GLAZE, recently retired from the National Bureau of Standards, has been awarded the U. S. Department of Commerce Silver Medal for Meritorious Service. He was assistant chief of the mineral products division glass section for 19 years.

Ford Motor Co.

Has completed an expansion program to more than double the capacity of its Nashville Ford Glass Plant. Production there is now expected to exceed 1100 tons of glass per day, with employment totalling more than 2500.

Harbison-Walker Refractories Co.

THOMAS WELFER elected secretary of the company, succeeding G. F. CRONMILLER, JR., who has retired as vice-president and secretary after 48 years of service . . . GEORGE M. ULLOM, Alabama district sales manager, died May 13 at the age of 55. He had been with the firm since 1929.

Pall Corp.

Has merged with Trinity Equipment Corp. of Cortland, N. Y., producer of dry air and gas systems, thermowells, and thermocouples. Trinity will continue as a wholly-owned subsidiary of Pall.

Flat Glass Jobbers Assn.

Will hold its 1961 Convention, August 7 to 10, at the Hilton Hotel in Denver, Colo. Seminars on the problems of glass distribution will be featured.

NEW APPLICATIONS IN GLASS...

Some 15,000 sq. ft. of float glass are used in the Canadian building shown here.

Float Glass in New Building

The first full-scale use of float glass in Canada was marked with the occupancy in May of the 615 Dorchester West building in Montreal. Float glass, developed in Britain, is produced by floating the molten glass on a surface of molten metal. Both the upper and lower surfaces of the glass are free from distortion and need no subsequent grinding as does plate glass. The result is a glass claimed to combine the luster of sheet glass with the perfect surface of plate.

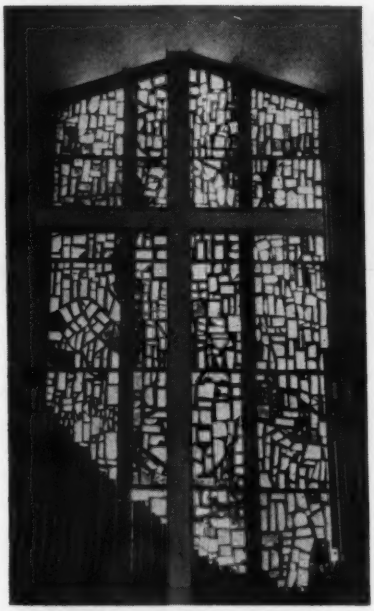
Pilkington Glass Ltd.

Reader Service Card: Circle No. 58

Glass as a Lubricant

Since steel requires heating to about 1200°C before melting, standard extrusion processes using dies and other apparatus have been limited in some respects. To overcome these limitations, Cefilac of France has developed the Ugine-Sejournet lubrication process in which, at high temperatures, glass acts as a lubricant similar to grease at lower temperatures. The application of this process will play an important role in extruding high-quality exotic and other high heat-resistant metals essential to the space age. *Curtis-Wright Corp.*

Reader Service Card: Circle No. 59



Epoxy-bonded stained glass window in Zion Lutheran Church, Houston, Texas.

Epoxy-Bonded Art Glass

An epoxy adhesive called "PlastXbond" can be used to bond art glass with the same effect as lead glass at less cost. The plastic seal provides adhesion stronger than the glass itself, an important factor in withstanding pressure from the wind. *Bradco Plastics.*

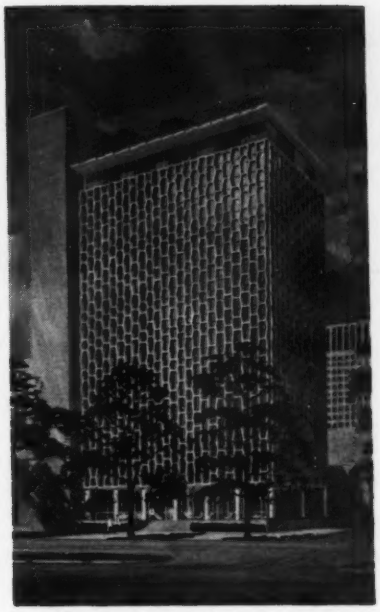
Reader Service Card: Circle No. 60

Safety Glass Controls Heat and Light

A laminated architectural safety glass called "Twi-Lite" is said to reduce the sun's energy by 40 per cent over clear glass and to allow an optional visible light transmission of only 28 or 9 per cent. Sound- and shatter-resistant, this new glass lowers initial air conditioning requirements considerably, eliminates the need for costly shading devices, and provides a saving in decreased breakage and replacement labor.

Also available is a new sound absorbent glass, "Acousta-Pane," which is treated with a special interlayer that converts sound energy into small amounts of heat instead of passing it through the pane as noise. Noise intensity level is reduced by as much as 66 per cent. *Amerada Glass Corp.*

Reader Service Card: Circle No. 61



Honeycomb over glass in new U. S. Mission to the United Nations.

Honeycomb and Glass

A honeycomb-like cast stone grille provides a striking variation on conventional curtain wall design in the U. S. Mission to the United Nations building. Each window and spandrel is framed in one of the 709 hexagonal units. The 14-in. overhang of the grille functions as an effective control for solar heat and light. Spandrels are of "Tempar-Glas"; windows pivot for easy cleaning. *Virginia Glass Products Corp.*

Reader Service Card: Circle No. 62

CATALOGS RECEIVED

Research on nonoxide glasses (50 pages). A report on progress in an Army project aimed at developing new types of nonoxide glass with higher melting and softening temperatures for missile use. *U. S. Department of Commerce.*

Reader Service Card: Circle No. 63

The report on Hermetite Corp.'s "High-Temperature Glass-to-Metal Seal" (THE GLASS INDUSTRY, May, 1961, page 273) should read "500°C to 600°C" and "800°C" where operating temperatures are given.

NEW EQUIPMENT AND SUPPLIES

Gas-Fired Infrared Burners

Designed for low-temperature commercial and industrial process heating. Manufactured in 6- by 12-in. sections and available in end-flanged or bottom-flanged sections.

Said to produce radiation equivalent to twelve 250-watt electric bulbs at normal grid operating temperatures of 900°F to 1680°F. Full-rated capacity for each section is 30,000 BTU/hour with turndown to 10,000 BTU/hour. *Eclipse Fuel Engineering Co.*

Reader Service Card: Circle No. 64

Pneumatic Conveyor Feeder

Measures 16 ft., 8 in. in length and has a 4- by 24-in. trough that can move bulk, granular material, or assembly parts at capacities up to 30 tons per hour. Flow rate can be changed by adjusting air pressure range from 20 to 70 psi. *National Air Vibrator Co.*

Reader Service Card: Circle No. 65

Gate Valves

Plastic-coated resilient-seat steel gate valves have high resistance to abrasion and corrosion. Suitable for use with process piping where abrasive-corrosive liquids and slurries are handled. *Edward Valves, Inc.*

Reader Service Card: Circle No. 66

Airjet Tank Rail Car

A new tank-type rail car has been designed for discharging bulk materials by air pressure directly into the plant, storage bin, or highway vehicle. Capacity is 2400 cu. ft. of dry material, and it can be unloaded by one man in 30 minutes. *Pullman, Inc.*

Reader Service Card: Circle No. 67

Dual-Purpose Furnaces

Are equipped with molybdenum disilicate heating elements. Suited for (*1*) firing in oxidizing or nitrogen atmospheres in the temperature range from 2600°F to 3000°F (1427°C to 1650°C), and (*2*) firing in atmospheres containing CO or H_2 up to 27302°F (1500°C). Available in cabinet, elevator, and shuttle kiln models. *Harrop Precision Furnace Co.*

Reader Service Card: Circle No. 68

Detachable Lightweight Vibrator

Powered by air; designed for all applications requiring occasional vibration. Weighs less than 70 lb. and operates on as little as 30 psig of air; can develop a force of over 1000 lb. *The Cleveland Vibrator Co.*

Reader Service Card: Circle No. 69

Solid State Regulators

Complete line of regulators and exciters for variable speed drives. Silicon controlled rectifiers and diodes are used in place of tubes. Said to achieve precise motor control, 0.1 per cent regulation at base speed, with response up to twice as fast as tube-type regulators. *Reliance Electric & Engineering Co.*

Reader Service Card: Circle No. 70

Cutting Machine

A simple easy-to-construct machine has been developed for the hot cutting of glass tubing. *Kimble Glass Co.*

Reader Service Card: Circle No. 71

Glass Coating

Is applied to windows and doors by means of gravity flow. Called "Glastint", it is said to control infrared and ultraviolet rays of the sun, reducing fabric fading by as much as 97.8 per cent, glare caused by direct contact of sun on glass by 92.8 per cent. Excess heat is absorbed by chemical arresters. Made in six light, transparent shades, three deep, glare tones, and three translucent frosts. *Solarex Corp.*

Reader Service Card: Circle No. 72

Pelletizing Discs

Are now being used for the agglomeration of a wide range of granular materials. These discs, once used primarily for preparing iron ore and cement sinter mixes, are said to have great potential in such fields as nonmetallic minerals, chemicals, glass, ceramics, clay, cement, lightweight aggregate, limestone, and coal. A number of materials previously regarded as waste products are now being pelletized, with many future applications expected. *Dravo Corp.*

Reader Service Card: Circle No. 73

Dust Collectors

Constructed of 3/16-in. polished aluminum, the dust collectors clean themselves in three ways: by periodic shaking of cloth filter tubes combined with reverse airflow through the filters; by continuous removal of collected material by an adjusted screw conveyor at the base; and by discharge of collected material through a rotary feed valve. Up to 58,000 cfm of air can be handled through a single 12-section model. Air-to-filter ratios vary from 5:1 to 25:1, depending on the application. *Tutomatic Collector Div., Torit Mfg. Co.*

Reader Service Card: Circle No. 74

Industrial Scale

Provides instant reading, with no oscillation of the indicating element. The illuminated projection type indication offers maximum reading ease from a wide angle, and a double-filament bulb provides instantly available standby illumination in case the main filament burns out. There is a choice of six avoirdupois or metric charts with capacities up to 30 lb. and 15 kilograms, respectively. Ask for Bulletin OL-875. *Toledo Scale Corp.*

Reader Service Card: Circle No. 75

Asbestos Clothing

Asbestos safety clothing said to shed 3000°F molten metal without deterioration, loss of resiliency, or discoloration of the inner side.

Lightweight garments reflect approximately 50 per cent of radiant heat. They are recommended for applications involving exposure to glass, chemicals, ceramics and oils. Clothing includes coats, leggings, cape sleeves, coveralls, sleevelets, spats, pants, chaps and aprons. *American Optical Co.*

Reader Service Card: Circle No. 76

Thermocouple Material

A ceramic-insulated, metal sheathed, spectrochemically clean thermocouple material has been developed for measuring temperature uniformly over entire sections of kilns. Designated "Tempak," it is manufactured for ordinary electrical leads with single or multiple conductors. Said to provide maximum protection where corrosion, high pressure, severe vibration, and extreme temperatures are present. *Temptron, Inc.*
Reader Service Card: Circle No. 77

Furnace Features Infinite Zone Control

Infinite zone control switches on "Dyna-Trol" industrial electric furnaces allow for complete and accurate equalization of vertical zone temperatures at any time-temperature curve. When desired temperature level between 500°F and 2300°F has been reached it can be maintained to a ±3°F dead zone or control band. Line fluctuation is automatically compensated. *L & L Mfg. Co.*
Reader Service Card: Circle No. 78

Block Valves for High Vacuum Systems

Series has a common bellows seal assembly for sizes less than 1 in. Machined from solid brass square stock, the porosity-free valves are available with in-line or angle configurations for soldered or screwed connections in sizes from ¼ to 1½ in. They are factory leak tested, have high conductance, and provide for maximum gas flow within compact design. *NRC Equipment Corp.*
Reader Service Card: Circle No. 79

Extension Wire

Multiple pairs of thermocouple extension wires are harnessed into special cables to cut the cost of thermocouple wiring by reducing installation and maintenance time, saving space, cutting material costs, and lowering final installed costs. From 4 to 48 pairs of extension wire are in each cable and all pairs are numbered. Available in 1000-ft. lengths. *Pyrometer Co. of America, Inc.*
Reader Service Card: Circle No. 80

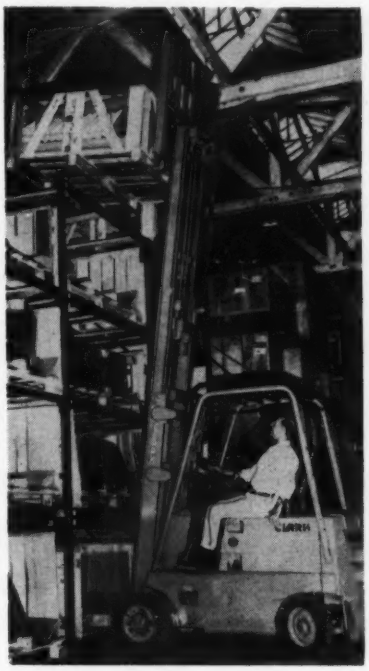
Nickel-Cadmium Batteries

Batteries with nickel- and cadmium-oxide active materials in perforated steel pockets of the positive and negative plates. Applications include: starting engines to generate emergency power; stand-by to assure continuous operation of microwave systems; emergency lighting systems; and switchgear tripping in electric utility substations.

There are 22 electrical sizes with 8-hour capacity ratings ranging from 10 to 450 ampere-hours. *Exide Industrial Div., Electric Storage Battery Co.*
Reader Service Card: Circle No. 81

High Lifting Fork Truck

A fork truck equipped with a triple-stage upright has been reported by a mirror manufacturer and distributor of flat, plate, and safety glass to increase warehouse storage space by 22 per cent. This new truck stacks to heights of 180 in. in aisles 108 in. wide. Capacity is 4000 lb. *Clark Equipment Co.*
Reader Service Card: Circle No. 82



Ultrasonic Device

Maintains cutting action of grinding wheels over extended periods of time. Called "Ever-Grind", it uses ultrasonic energy to prevent loading. *Cavitron Corp.*
Reader Service Card: Circle No. 83

All-Purpose Cleaner

Can perform vacuuming, blowing, air sweeping, and spraying operations. Features large rear wheels for maximum mobility, a holder for carrying attachments, and a handle for easy maneuvering. *Ace-Sycamore, Inc.*
Reader Service Card: Circle No. 34

CATALOGS RECEIVED

Instruments and controls (4 pages). Describes fluid meters for recording, indicating, and integrating, transmitters and recorders for pressure and draft, level transmitters, and temperature instruments. *Bailey Meter Co.*
Reader Service Card: Circle No. 84

Diamond saw blades. The exact grade of blade to use, recommended depth of cut and speed of operation for sawing glass block, refractory brick, other materials. *J. K. Smit & Sons, Inc.*
Reader Service Card: Circle No. 85

Rare earths (8 pages). Revised brochure contains complete technical information about thorium, yttrium chemicals, metals, and alloys of the rare earth group of elements. *Vitro Chemical Co.*
Reader Service Card: Circle No. 86

Atomic energy levels in crystals (84 pages). A theoretical study of the sharp line absorption spectra of crystals. *U. S. Department of Commerce.*
Reader Service Card: Circle No. 87

Borax (32 pages) Booklet outlines history, development research, mining processes; principle products, including fiber glass, which contain borax are discussed. *U. S. Borax & Chemical Corp.*
Reader Service Card: Circle No. 88

Refractory insulating materials (4 pages). Describes "M-Block" products for use in blast furnace stoves, refractory back-up, ceramic kilns, annealing pits, and heat-treating furnaces. Included is an outline of recommended insulation thicknesses for various temperature ranges, physical properties of the material, thermal conductivity data, and shipping information. *Kaiser Refractories & Chemicals Div.*
Reader Service Card: Circle No. 89

Fire blanket (2 pages). Compact wool blanket snuffs out flames from head to foot when clothing is set on fire. *Mine Safety Appliances Co.*
Reader Service Card: Circle No. 90

Safe packaging of glass (10-minute film). Newly-released 16-mm sound and color film tells the story of "Safepak", a product developed for shipping windshields. Available as a free loan to those in the transportation, glass, and packaging fields. *Shatterproof Glass Corp.*
Reader Service Card: Circle No. 91

INVENTIONS AND INVENTORS

Sheet and Plate Glass

Apparatus for Surfacing Glass. Patent No. 2,945,330. Filed January 17, 1957. Issued July 19, 1960. Two sheets of drawings; none reproduced. Assigned to Societe Anonyme des Manufactures des Glaces et Produits Chimiques de Saint-Gobain, Chauny & Cirey, by Ivan Peyches.

This invention concerns the continuous process of glass surfacing, i.e., a process where the sheet glass moves at a slow pace along a straight path and is ground and polished by means of tools arranged one after the other along the path of the glass. These tools, which exercise a certain pressure on the glass, are given a surfacing motion on the surface of the glass, and they are supplied with grinding or polishing abrasive grains, which are fed between the tools and the glass in order to rub the glass and surface it. The nature and size of the abrasive grains and the material of the rubbing surface of the tools vary according to the purpose which they are designed to effect.

In constructing the apparatus of the invention, one may utilize any means which will produce in the tool a rapid, periodic motion of small amplitude, for example, a circular movement of translation can be obtained by giving to two points of the tool an identical circular rotational movement in synchronism. It is also possible to obtain this result by combining two straight line oscillatory movements perpendicular to each other of the same size but in quadrature. If, on the contrary, these oscillatory movements are of amplitudes and periods that are variable, the resulting movements will be in the form of pseudo-ellipses, similar to the figures of Lissajou, of which the axes vary in dimensions and/or in direction, constantly and rapidly, and which are within the scope of the invention. These movements can be obtained, for example, by means of vibrations generated by electromagnets.

There were 16 claims and the following references cited in this patent.

United States Patents

1,962,766, Crowley et al., June 12, 1934; 1,962,767, Crowley et al., June 12, 1934; 2,690,036, Baldridge, Sept. 28, 1954.

Treating Glass Sheets. Patent No. 2,943,963. Filed February 14, 1957. Issued July 5, 1960. One drawing; not reproduced. Assigned to Pittsburgh Plate Glass Company by Herman R. Marini, William O. Lytle, Arnold E. Saunders, and William E. Wagner.

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In the fabrication of complex windshields, if the bent glass sheets are misaligned after insertion of the plastic interlayer, there is considerable chance of breakage either in the prepressing apparatus or in the autoclave. The present invention relates to a method of insuring that the complexly shaped glass sheets are matched properly when they are reassembled with the plastic interlayer.

The present invention uses a pair of spaced spots of a glass staining composition on a surface of one sheet only of a bending doublet before the sheets are stacked on a mold for bending. The staining composition selected is one that transfers a portion of its stain to each sheet of the doublet only after exposure to elevated temperatures approximately equal to glass softening temperatures for a time-temperature cycle experienced by the bending doublet in commercial bending operations. The spots are applied adjacent the margin of the sheet to insure that they are hidden by a frame in which the curved laminated assembly is mounted.

The solids mixture used is shown in Table I:

Table I

	Parts by Weight
AgCl	40
$CuSo_4$	10
Yellow ochre (a hydrated iron oxide which may contain a small amount of clay)	50

To 100 grams of the mixture in Table I was added 200 cubic centimeters of methanol plus 20 cubic centimeters of pine oil. The resulting mix was ball milled for 17 hours, a workable slurry for use as a staining composition.

There were 16 claims and the following references cited in this patent.

United States Patents

1,646,468, Warga, Oct. 25, 1927; 1,948,636, Tillyer, Feb. 27, 1934; 1,996,549, McNutt, Apr. 2, 1935; 2,324,-433, Scheetz, July 13, 1943; 2,330,193, Blau, Sept. 28, 1943; 2,367,111, Fowler et al., Jan. 9, 1945; 2,662,036, Levi, Dec. 8, 1953; 2,734,840, Kane, Feb. 14, 1956; 2,880,553, Carson, Apr. 7, 1959.

Foreign Patents

201,285, Australia, Apr. 4, 1956.

Tube and Cane Machines

Method of and apparatus for manufacture of the glass envelope for a cathode ray tube. Patent No. 2,886,920. Filed April 7, 1954. Issued May 19, 1959. No sheets of drawings; none reproduced. Assigned to The General Electric Company, Ltd. by Robert Leonard Breadner, and Charles Henry Simms.

According to the invention, a method of manufacturing a glass body comprising a relatively thick main wall portion and a relatively thin-walled neck portion extending from an aperture in the main wall portion, and wherein the shapes of the glass surfaces at the adjoining parts of the neck and main wall portion are required to be carefully controlled includes the steps of forming the main wall portion continuous where said aperture is to be formed, heating the main wall portion in the

(*Continued on page* 410)

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CURRENT STATISTICAL POSITION OF GLASS

Employment in the glass industry during March, 1961, was as follows: *Flat Glass*: a preliminary figure of 23,300 for March, 1961, indicates an increase of 0.4 per cent over the adjusted figure of 23,200 for February, 1961. *Glass and Glassware, Pressed and Blown*: an increase of 1.4 per cent is shown by the preliminary figure of 86,100 reported for March, 1961, when compared with the adjusted figure of 84,900 reported for February, 1961. *Glass Products Made of Purchased Glass*: the preliminary figure of 12,900 given for March, 1961, is 2.2 per cent under the adjusted figure of 13,200 reported for February, 1961.

Payrolls in the glass industry during March, 1961, were as follows: *Flat Glass*: an increase of 0.6 per cent is shown in the preliminary $12,347,273.47 given for March, 1961, when compared with February's $12,263,117.94. *Glass and Glassware, Pressed and Blown*: an increase of 1.5 per cent is shown in the preliminary $35,158,239.31 given for March, 1961, when compared with the previous month's adjusted $34,605,690.82. *Glass Products Made of Purchased Glass*: a preliminary figure of $4,164,229.65 was reported for March, 1961. This is a decrease of 2.2 per cent when compared with the adjusted figure of $4,261,072.20 for February.

Glass Container Production based on figures released by the Bureau of the Census, Industry Division, was 13,538,000 gross during April, 1961. This is a decrease of 10.8 per cent under the previous month's production figure of 15,171,000 (revised) gross. During April, 1960, glass container production was 12,732,000 gross, or 5.9 per cent less than the April, 1961, figure. At the end of the first four months of 1961, glass container manufacturers have produced a preliminary total of 53,516,000 gross. This is 2.3 per cent more than the 52,287,000 gross produced during the same period in 1960.

Glass Container Shipments during April, 1961, came to 11,091,000 gross, a decrease of 37.02 per cent under the March figure of 17,613,000 (revised) gross. Shipments during April, 1960, amounted to 12,822,000 gross, or 15.6 per cent more than April, 1961. At the end of the first four months of 1961, shipments have reached a preliminary total of 51,598,000 gross which is 6.3 per cent more than the 48,537,000 gross shipped during the same period of the previous year.

Stocks on hand at the end of April, 1961, came to 21,777,000 gross. This is 12.2 per cent more than the 19,410,000 gross on hand at the end of March, 1961, and 3.4 per cent more than the 21,052,000 gross on hand at the end of April, 1960.

GLASS CONTAINER SHIPMENTS

(All Figures in Gross)

Narrow Neck Containers

	April, 1961
Food	1,128,000
Medicinal and Health Supplies	994,000
Chemical, Household and Industrial	841,000
Toiletries and Cosmetics	792,000
Beverage, Returnable	733,000
Beverage, Nonreturnable	217,000
Beer, Returnable	285,000
Beer, Nonreturnable	1,301,000
Liquor	756,000
Wine	396,000
Subtotal (Narrow)	7,443,000

Wide Mouth Containers

Food	*2,695,000
Medicinal and Health Supplies	292,000
Chemical, Household and Industrial	130,000
Toiletries and Cosmetics	306,000
Dairy Products	92,000
Subtotal (Wide)	*3,515,000
Total Domestic	10,958,000
Export Shipments	*133,000
TOTAL SHIPMENTS	*11,091,000

* This figure includes Fruit Jars, Jelly Glasses, and Packers' Tumblers.

GLASS CONTAINER PRODUCTION AND INVENTORY

(All Figures in Gross)

		Production April 1961	Stocks April 1961
Food, Medicinal and Health Supplies; Chemical, Household and Industrial; Toiletries and Cosmetics.	Narrow Neck	4,611,000	6,998,000
	Wide Mouth	*4,392,000	*6,631,000
Beverage, Returnable		935,000	2,812,000
Beverage Nonreturnable		335,000	517,000
Beer, Returnable		368,000	676,000
Beer, Nonreturnable		1,480,000	1,517,000
Liquor		883,000	1,610,000
Wine		415,000	719,000
Dairy Products		119,000	297,000
TOTAL		*13,538,000	*21,777,000

* This figure includes Fruit Jars, Jelly Glasses, and Packers' Tumblers.

NEW BOOKS

ULTRASONICS AND ITS INDUSTRIAL APPLICATIONS, by O. I. Babikov. Translated from Russian and published by Consultants Bureau Enterprises, Inc., 227 W. 17th St., New York 11, N. Y. 230 pages. $9.75

Although this volume covers recent Soviet advances in the field, its scope is universal. The author discusses fully, ultrasonic control methods, the action of high-intensity ultrasonic oscillations on various technological processes, ultrasonic drilling techniques, and ultrasonic pulse methods of flaw detection and physicochemical research. Also, the fundamental physical principles are presented in concise form, which makes the publication a convenient reference for all technicians working in industrial research, metallurgy, acoustics, and the many related fields of physics and chemistry.

THE STRUCTURE OF GLASS, Volume 2. Proceedings of the Third All-Union Conference on the glassy state, held in Leningrad, November 16-20, 1959, published in September, 1959, by Consultants Bureau Enterprises, Inc., 227 W. 17th St., New York 11, N. Y. 430 pages. $25.00

Volume 2 contains papers presented at the conference convened by the Institute of Silicate Chemistry of the Academy of Sciences USSR, the D. I. Mendeleev All-Union Chemical Society, and the S. I. Vavilov (Order of Lenin) State Optical Institute for discussion of recent experimental studies of various properties of glass, the principal methods for investigating glass structure, and the problem of glass formation.

The research results of such well-known scientists as A. A. Lebedev, A. G. Vlasov, M. A. Bezborodov, and N. V. Belov, are printed in full, with all tabular material, diagrams, and photographs integrated with the text.

LITERATURE REVIEW OF INFRA-RED ENERGY PRODUCED WITH GAS BURNERS. Research Bulletin No. 83. Order Dept., Committee on Industrial and Commercial Gas Research, American Gas Association, 420 Lexington Ave., New York 17, N.Y. $2.00

This bulletin contains an extensive evaluation of the available literature pertaining to infra-red energy. Gas-fired infra-red burners are described and evaluated, and their energy output is compared to infra-red energy generated by other means.

The bulletin describes many current applications and includes a listing of possible future applications.

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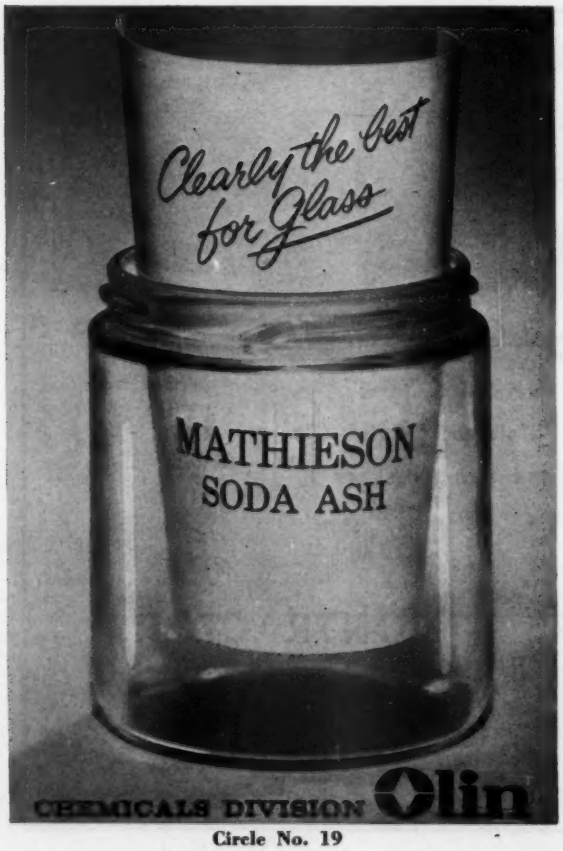

Circle No. 19

CHEMICAL ANALYSIS OF GLASS

(*Continued from page* 380)

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16. Segatto, P. R., "Analysis of Boron in Borosilicate Glasses by Neutron Transmission," *J. Am. Ceram. Soc., 43,* 278 (1960).
17. Adams, P. B., and Williams, J. P., "Fluoride Analysis of Glasses and Silicate Materials by Pyrohydrolysis Separation," *J. Am. Ceram. Soc., 41,* 377 (1958).
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GLASS DIVISION PAPERS

(*Continued from page* 383)

The Role of Phase Equilibrium Considerations in Crystallization Studies of Glasses. By Rustum Roy, Pennsylvania State University. The purpose of this paper was two-fold: first, to draw attention to the relative "stabilities" of the crystalline and other phases which can precipitate from many useful glass compositions and the implication that this precipitation has for a description of the sequence of events in glass crystallization; second, to illustrate the importance of the possibility of the formation of two liquid or short-range-order (=SRO) phases as the first "observable" step in the crystallization of certain glasses.

The paper considered the phase relations between composition of phases and temperature (and pressure) in the final stages of crystallization of glasses because these relations are determinative of the final reactions which must occur during equilibriation. In the earliest stages of nucleation, structural conditions predominated in determining the nature of the nucleus. However, in all glass-crystallization studies where time was a factor, the phase equilibrium relations invariably indicated the direction of changes with time. Thus, while metastable crystallization of a particular phase was common in silicate melts, the reactions of the nucleus with its environment must be consonant with the requirements of the equilibrium diagram.

Examples of metastable equilibria in silicate systems were cited to illustrate not only the importance of structure of the glass, but also the "equilibrium" aspect of such crystallizations.

Processes of Diffusion and Formation of Bubbles During Crystallization and Remelting of Crystals in Glass. By G. Pecriaux and E. Plumat, Union Verreries Mechaniques Belges, Charleroi, Belgium. Presented by Delbert Day, Pennsylvania State University. Glass devitrification was studied in various materials. The diffusion of O_2, N_2, and H_2O gases, was examined par-

ticularly during the processes of crystal formation or melting. In a soda-calcium glass, various crystals were found to be growing: cristobalite, wollastonite, diopside, and devitrite—all as a function of the chemical composition. The remaining vitreous phase was different in each instance; consequently, the gas solubility and the diffusion rate in these phases were different.

It appeared that the bubble formation during the devitrification depended on several factors.

1. The nature of the primary crystalline phase: other conditions being equal, more bubbles were noticed in the silica crystal neighborhood.
2. The importance of the developed crystalline phase: the amount of dissolved gas in the glass before and during the devitrification period being taken into consideration, the bubbles only arose in the neighborhood of the crystals from the moment that the crystal weight/vitreous phase weight ratio reached a minimum value.
3. The nature of the dissolved gas: qualitatively, it can be determined that the gaseous phase which developed during the devitrification was more important in the presence of air, oxygen, and nitrogen than in the presence of water vapor.

Crystal Nucleation by Glass in Glass Separation. By S. M. Ohlberg, H. R. Golob, and D. W. Strickler, Glass Research Center, Pittsburgh Plate Glass Co. Three examples were given of crystallizable glasses which were internally nucleated by a glass in glass separation. In a SiO_2-TiO_2-Al_2O_3-MgO system, the droplets formed spontaneously on cooling, and on gentle heating they reached a critical size, 500 Å, after which a glass-crystal transformation occurred. In a SiO_2-TiO_2-CaO-Li_2O system, the droplets having a diameter of 2000 to 4000 Å also formed spontaneously on cooling. When this glass was reheated, crystal growth in the matrix initiated at the droplet-matrix interface. Finally, in a SiO_2-Al_2O_3-MgO-Li_2O system, metastable droplets as large as 60 microns were formed by careful heat treatment. Again crystal growth at the droplet-matrix interface was detected. This time crystallization extended into the droplet first. A new mechanism for the growth of spherulites was also indicated by this latter work.

The three glasses had in common the fact that they could be uniformly devitrified by an internal nucleation process as opposed to the more common surface nucleation and devitrification. For each glass evidence was presented which demonstrated that internal nucleation was the result of a glass in glass separation.

Chemical Resistivity of Fused Silicate in the System SiO_2-Al_2O_3-CaO-Na_2O as a Function of Nucleated Crystallization. Read by Charles Booth, Pennsylvania State University, in absence of the author, B. P. Locsel, Budapest, Hungary. The chemical resistivity of crystallized glasses in the system SiO_2-Al_2O_3-CaO-MgO-Na_2O nucleated by heavy metal sulfides was discussed in relation to the effect of the amount of glassy phase and the dimension of individual crystals of the silicates.

(To be concluded next month.)

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FIBER GLASS REINFORCEMENT

(*Continued from page* 396)

permissible and standard plastic turning techniques are suggested. Where production-finishing techniques such as drilling or turning are involved, it is recommended that carbide tipped tools be used. Wet grinding of close tolerance cams has been achieved with complete success.

These materials may be bonded using the same adhesives as would be applied to the equivalent unfilled grades. In the case of reinforced polystyrene, it is advisable to body-up the solvent-type adhesives with some plain polystyrene pellets. This is necessary because the surface area is 30 per cent glass and the additional body tends to fill in voids and give better bonding.

Extrusion

While a program is underway to develop extrusion techniques for fiber glass reinforced materials, it has not progressed to the point where data can be released. Therefore, it is suggested that processing by this method be avoided until the necessary data has been gathered.

In summation, it can be seen that fiber glass reinforced compounds, because of their improved properties, tend to further fill the gap between the plastics and the metals. Their high mechanical characteristics, coupled with the low unit cost inherent in the molding process, offer some very interesting potentials.

INVENTIONS AND INVENTORS

(*Continued from page* 403)

region where said aperture is to be formed so as to soften the glass, pushing the softened glass into the form of a neck, and shaping the surfaces of the adjoining parts of the main wall portion and neck by applying a shaped body against one side of the glass so as to press the softened glass against a cooperating shaped surface of the forming tool on the other side of the glass.

The forming tool preferably had a substantially cylindrical surface at the end which enters into the neck as and when formed, and this cylindrical surface flares outwards at the other end of the tool so that the outer surfaces of this flared portion and the adjoining part of the cylindrical portion provide the said shaped surface of the forming tool.

Where it is possible to rotate the glass body during the heating and neck forming process, this will be desirable for shaping and heating of the glass.

United States Patents

742,345, Mygatt, Oct. 27, 1903; 1,699,305, Meyer, Jan. 15, 1929; 2,102,357, Dichter, Dec. 14, 1937; 2,266,417, Eisler, Dec. 16, 1941; 2,410,345, Hinkley, Oct. 29, 1946; 2,662,346, Giffen, Dec. 15, 1953.

Glass Wool and Fiber

Method of Making Transparent Unsaturated Polyester-Styrene-Glass Fiber Composition. Patent No. 2,944,994. Filed July 7, 1954. Issued July 12, 1960. Two sheets of drawings; none reproduced. Assigned to H. H. Robertson Company, by Fred G. Singleton and Kenneth A. Schafer.

The present invention is based upon the discovery that the visibility of the fiber reinforcement in a fiber reinforced plastic material may be substantially decreased, and conversely the light transmitting characteristics of particular types of fiber reinforced plastic material, particularly in sheet form, may be greatly increased by the use of a resin which in its cured state has a light refractive index approaching the light refractive index of the particular reinforcing fibers embedded therein.

The reactants were placed in a 5-liter three-neck flask equipped with a mechanical agitator, an inlet tube for nitrogen gas, and means for collecting the water formed during the reaction. The temperature was raised over a period of one hour to 200°C and was maintained at this level for an additional three hours. The product was then cooled to 80°C and dissolved in sufficient styrene monomer to produce a solution having a viscosity of 200 centipoises at 25°C. Sufficient t-butyl catechol was added to the styrene prior to its addition to the polyester to make 300 parts per million based on the total weight of polyester and styrene. A casting was made from the resin by catalyzing it with one per cent of benzoyl peroxide and heating it in a glass mold. The index of refraction of the cured unreinforced material was 1.5320 when measured at 20°C using the sodium D line, which compares quite closely to the glass fibers used in reinforcing.

There was one claim and the following references cited.

United States Patents

2,176,837, Ellis, Oct. 17, 1939; 2,311,613, Slayter, Feb. 16, 1943; 2,491,409, Kropa, Dec. 13, 1949; 2,542,819, Kropa, Feb. 20, 1951; 2,650,184, Biefeld, Aug. 25, 1953; 2,743,309, Lindsay, Apr. 24, 1956; 2,801,919, Eichorn, Aug. 6, 1957.

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Handbook of Chemistry and Physics, 28th edition (1944), published by Chemical Rubber Publishing Co., Cleveland, Ohio, page 2145.

Wakeman: *Chemistry of Commercial Plastics* (1947), published by Reinhold Publishing Corp., New York, page 503-507.

Flory: *Principles of Polymer Chemistry* (1953), published by Cornell Univ. Press, Ithaca, New York, page 31.

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